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ERGOT OF GRAINS AND GRASSES

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1920.

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INTRODUCTION

Ergot of certain grains and grasses and the causal organisms have been, for many generations, the subject of extensive and carefully conducted investigations and yet there remain phases of the problem not well understood which need further attention by the mycologist and plant pathologist.

This paper is the result of a study of the literature on the genus Claviceps and has for its object the summarizing of the results of investigations and observations on the subject to date.

In the bibliography are included only works having some distinct bearing upon the problem. In some cases the original papers were not accessible. Then use was made of abstracts. In very few cases neither originals nor abstracts could be secured. Citations to such works, however, because of their possible importance, have also been included in the bibliography.

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GENERAL CONSIDERATION OF THE DISEASE

Ergot is a disease of grains and grasses caused by several species of fungi belonging to the genus Claviceps. The most common, the earliest known, and the best understood species of the genus is C. purpurea Tul. Concerning this species we possess an extensive literature, whereas concerning the others we have but short and rather inadequate taxonimic descriptions. It may be said that practically the entire literature on ergot deals with C. purpurea. Because of this, some chapters in this paper, especially the first five, apply almost, if not entirely, to this species, there being in the majority of cases, no information concerning the other species on the points considered. It is, however, supposed that what is written of C. purpurea is true in a general way also of the other species of the same genus, although here too there is, in the majority of cases, still no supporting experimental evidence.

COMMON NAMES

The name "ergot" is the term commonly used for the disease in this country, although in some sections of the country and also in some textbooks it is spoken of and described as spurred rye, "spur" being a translation of the French "ergot", meaning rooster's or cock's spur, which name was early applied to the disease by French writers. In England it is known as cockspur, black grain of corn, and ergot; in France, as "l'ergot du siegle", "siegle cornu", and "siegle ergoté"; in Germany, most commonly as "Mutterkorn", but also as "Kornzapfen","Hungerkorn", "Roggenmutter", "Martinskorn", "Äfterkorn", "Hahnsporn", "Todtenkopf", and "Gerstenmutter"; in Italy, as "sporon di gallo", "chiodo segalino", "grano sprone", etc.; and in Russia, as "spornija".

DESCRIPTION

All Claviceps species attack only the heads of the grain or grass, or rather only single flowers scattered here and there in the head. The embryos of the flowers are first infected and may be practically destroyed before

there are any visible signs of parasitic growth. Externally, such flowers of the host, as for instance of a young rye plant from which later sclerotia develop instead of seeds, often have the appearance of the healthy and normal ones. Its normal tissues, however, may have already been replaced by a fine, yellowish-white fungous growth. The exterior of this growth, visible when the flower is opened carefully, is divided by sinuous furrows into more or less uniform sections. As the fungus develops further, finally occupying practically the whole interior of the grain, there also appears a slimy, insipid, sweetish, somewhat cloudy liquid, which is probably a secretion product of the mycelia. In this liquid are set free the fungal conidia, giving it the cloudy appearance. This liquid soaks through the glumes of the flower and collects in drops on them or at their bases. It is called "honey dew", and the stage of the fungous development at which dew is secreted is called the "sphacelial" stage, "Sphacelia" being the generic name of the conidial stage of Claviceps. The amount of "dew" and the length of time during which it is secreted depend upon the rapidity and amount of fungous growth.

While the "honey dew" continues to be secreted in drops, the mycelia at the base of the invaded embryo send out considerably thicker branches. These unite from below upwards into a uniformly thick, hard body on the exterior of which the fungous threads build a dense layer, reddish to violet in color. The body thus formed is the young sclerotium on whose apex the fungous threads continue to grow uniformly. Later these threads dry out, forming what is called the "cap" usually found on the apex of the ripe sclerotium. These ergot kernels or sclerotia are scattered throughout the head, more commonly at the lower or middle part, and are commonly long, extended, somewhat curved, longitudinally furrowed, cylindric bodies. On the outside they are grayish-violet, sometimes also with a dusty appearance due to a coating of waxy scales.

GEOGRAPHICAL DISTRIBUTION

The distribution of ergot is very general with the distribution of

the hosts on which it occurs, especially with that of rye. The disease has been reported from North and South America, Europe, Asia, Australia and Africa In North America it has been found in Vermont, Connecticut, New York, Michigan Indiana, Tennessee, Wisconsin, Minnesota, Iowa, Kansas, Wyoming, Montana, and other states, besides various places in Canada. It has been located in parts of South America. In Great Britain it has been found in England and Ireland. It has been reported from Belgium, Holland, Denmark, Norway, Sweden and Finland. and from various parts of Germany, Austria, Hungary and France, where it is common in the districts of the Marne and Cologne. In Switzerland it has been observed in Wildeswil, Meiringen and Rütti. In Italy, ergot has been reported from Tornetti, Avellino and Pavia. It has been stated also that its occurrence is common throughout the Balkan peninsula, but it has been reported only from Servia and north and south Bulgaria. It is very common in European Russia throughout the northern, eastern and middle parts, and in Caucasus and Transcaucasus. It is very abundant in Siberia, where two of the most important ergot trading centers are located - Tomsk and Omsk. It is reported also from other parts of Asia, from Australia, from Auckland (New Zealand) and also from Elsenburg, Cape Colony (Africa).

Ergot is as common in the elevated and mountainous regions as it is in the plains. Anderson (5)[1] found C. purpurea everywhere in Montana, as common at 8000 feet as at 3000 feet, the average altitude of Montana's plains. Kühn (145) found ergot in abundance on Agrostis vulgaris and Nardus setricta in "Marischen Gesenke" at an altitude of over 4000 feet. Voglino noted that the attack of ergot was more severe in the mountainous part of Italy. Cockerell (43) found C. purpurea as high as 8400 feet, but rather locally distributed. Frank (70) states that ergot in the mountains up to the upper limit of cereal cultivation, ans is here often as common as it is in the lower regions.

---

(1) Reference is made by number to "Bibliography".

Luerssen (164) found ergot in the high mountains as well as in the plains. Stäger secured ergot on several plants from the peak of Merbabu (3119 m.), Java.

ECONOMIC IMPORTANCE

Ergot is an important disease on rye and some of the grasses, but relatively unimportant on wheat, barley and oats. It is important from two different standpoints: first, because it decreases the yield and quality of the grain and hay; second, because infected grains and hay are injurious to stock when fed.

In general the decrease in yield and quality of grain due to the various species of Claviceps, especially *C. purpurea*, varies with season and locality. Grains, especially rye, in some seasons and in some fields are infected so heavily that nearly every head may have one or more sclerotia, as was reported from Wisconsin in 1917 (196). Cases where from 20 to 50 per cent of the heads were infected with ergot have been reported from various parts of the United States and from Europe. During the wet season of 1894 it occurred to a greater extent in Germany, the loss on rye being estimated at 1.6 per cent of the average yield, in contrast with the average annual loss of 0.3 per cent. The amount of ergot for 1917 in Connecticut ranged from one to five per cent. Decrease of the yield by as high as 20 per cont has been reported from Russia (120).

The injury to grasses appears to be greater than to grains. Heals and Peters (93) report that hay which consists largely of *Agropyron occidentale* and rye grass of different species, may contain as high as five or six per cent of ergot by weight. Single heads of these grasses may produce from one to forty ergot kernels. Rostrup (224) found sclerotia of *C. microcephala* on *Phragmites communis* so abundant that all examined infloresences had many hundreds of them. On one single panicle Rostrup (223) counted 912 sclerotia.

He found also that a sample of Festuca had 2700, one of Poa 5600, one of Holcu 500 and two seed samples of Agrostis alba had 2500 and 2700 sclerotia per pound respectively. Not a few cases have occurred (79), especially in Irelan and the United States, where hay was found to contain one eighth of its weight of ergot. Cockayne (42) did not find one out of over 100 samples of rye gras in Manawatu district, New Zealand, which was free from ergot. Most of them had not more than 2 per cent by weight, but samples containing as much as 30 per cent have been seen by him. It is heavier than the rye grass seed and so makes the price of the seed higher.

The loss to the farmer due to feeding grains and hay containing ergot may also become considerable under certain conditions. Very little is known, however, concerning the exact loss in stock fed on ergotized hay and grains. One case is reported in England where a Shropshire breeder lost L1200 in three years because of the prevalence of ergot in his fields. During the winter of 1901 the loss of live stock from eating ergotized grain was very great in many counties in Nebraska. Losses of cattle and horses in small numbers due to eating of ergotized hay or grain have been reported from various parts of this and other countries.

HISTORY

Ergot is one of the oldest known plant diseases. Its early history is connected with epidemics among both people and animals. As early as Caesar's and Galen's[1] time we find records of such epidemics of human disease which were attributed to poisonous impurities of grains. Knowing now that ergot possesses very marked toxic properties, we are lead to think that such impurities were due, at least in part, to the presence of ergot. Also it seems probable that the epidemics recorded during the middle ages as "Ignis sacer" were at least partly due to poisoning caused by eating ergotized food.

(1, Galen, Claudius, Greek physician and medical writer. A. D. 130-200 ?

Although the true nature of ergot was not known by early writers, its occurrence and use as a drug is mentioned by many of them. Lonicer, about the middle of the sixteenth century, mentions its specific use; Thalius applied the name of "ad sistendum sangiuneum"; Bauhin used the name of *Secale luxurians*; DeCandolle calle it *Sclerotium clavus*. Plenk (1795) noted ergot on rye and several grasses and described it as a degenerated kernel. This conception of ergot was prevalent for some time and was supported strongly even up to the middle of the nineteenth century by Fée and Phöbus (195). They first held that the ergot sclerotium does not have any spores or asci, but contains abnormally developed starch grains and that its external covering consists of the integument of the rye kernel. Phöbus, on the contrary, considered the contents of the sclerotium as modified albumen, the outer layer being the "shell" of the kernel. Others, as Bernhard, Willdenow, and Link, expressed similar interpretations. Bose, Rosier, and DeBomare (161) attributed ergot to a superabundance of nutritive material. Geoffray and DeJussieu regarded it as "a result of lack of equilibrium in the processes of fertilization." According to Fries' first conception, the sclerotia on the plant tissue correspond to the "indulations" on the animal tissue. To Raspoil (206) ergot is the product of the presence of a "vibrion". According to Karl Müller (131) ergot is the pathologically modified kernel, which modification is brought about by the failure of the flower to become fertilized. Schleiden (129) considered the formation of ergot sclerotia as an abnormality in cell structure brought about by improper nutrition. It was thought also that ergot was formed as a result of wounding of the plant heads or the young fruit through the sting of certain thrips (89) or the biting of a beetle, *Rhagonycha melanura* Fabr., which is very common in the field at the time of wheat blossoming (4). Staudinger (258) considered it as a "Product einer widernatürlichen Gährung in

feuchter witterung." Bauer (15) thought that the ergot sclerotium was merely a monstrosity or transformation of the embryo of the "germens" of rye and those gramineous plants which are subject to the disease. Concerning the cause of it he is not certain, but he considers that it is neither due to the rainy and wet seasons nor to insect attacks but that it may be induced by certain conditions of the soil. Fries in his later work described in 1829 the sclerotium of ergot as a fungus under the name of *Spermoedia clavus*, but he still believed that the whole sclerotium was a diseased grass seed and again expressed this opinion in his publication of 1849 (74).

Léveillé (154), in 1820, noticed that the ergot commenced with honey dew secretions, and considering this stage to be a distinct fungus parasitizing the ergot sclerotium, he proposed for it the name of *Sphacelia segetum* Since his time many others, Philidor, Quekett, and J. Smith, have vainly attempted to explain the question of ergot formation.

J. Smith (236) considered ergot to be a "constitutional disease of the plant, brought about by the reproductive bodies of the fungus (conidia found in the "honey dew") being absorbed during germination, and carried up by the fluids of the plant and becoming developed in the fructification even before the opening of the floral envelopes, but whether the ovarium is infected with the disease at this time or whether it is communicated to it during impregnation from the already diseased anther, is a question still to be seen."

In 1842, in his Mémoire sur la genre Sclerotium (156), Léveillé, to whom we owe the first information regarding the true nature of ergot, again expressed the opinion that ergot was a monstrosity of grass seed. While Léveillé, whose work has been duplicated without exception, explained the nature of the sclerotia of other plants, he still considered the ergot sclerotium of the grai and grasses (now called *Sclerotium clavus* by DeCandolle) as a degenerated kern

which harbors the white fungus or "honey dew" secreting fungus previously described by him under the name Sphacelia segetum Lév.

The step toward the establishing of the relation between the white fungous growth on the rye spikelets and the later appearance of the violet ergot, was made without Léveillé's knowledge one year before this. Meyen (175) published in 1841 his observations on ergot and proved that ergot developed from the fungus Sphacelia segetum. Meyen considered the Sphacelia as the mycelium of the ergot sclerotia. Corda (46), on the other hand, thought that the Sphacelia was the product of the sclerotia. He described in detail the morphology of ergot sclerotia and speaking of the outer dark covering of the sclerotium he says, "on the exterior of this layer is resting the spore forming layer of the fungus. This consists of fibrous, simple, one-celled non-septated basidial cells of white color on whose ends are borne the spores." Fries noticed the germinating ergot sclerotia and the formation of stromata with perithecia, but thought it was an independent fungus and called it Sphaeria purpurea.

Durien (260) first showed that when ascospores from the stromata fell on heads of cereal plants ergot resulted. While this was a considerable step towards the solution of this problem, one more important question remained to be answered, i.e., what becomes of the sclerotia which we call ergot? This question was solved by Tulasne in 1852 who planted a great number of ergot sclerotia in flower pots. He saw, as had others before him, a fungus appearing on these sclerotia in the form of stromata. The value of Tulasne's contribution consists in showing that the purple stromata (Claviceps purpurea Tul.) do not appear accidentally on the sclerotium of ergot as had been thought by previous workers, but are a direct fruiting form of the same; that the ergot sclerotia are merely the hibernation or resting stages of the same fungus,

which finally appears in the form of a white mycelial growth and known under the name, Sphacelia segetum Lév. The latter, in order to hibernate, passes into the hard sclerotia form, which in turn develops into a Pyrenomycete. Following this classical piece of work Kühn came out with his works on this subject in which he repeated Tulasne's work and fully completed the life history of Claviceps species known at that time. Since Kühn's time till very recently the technical work on ergot has been of comparatively minor importance The recent work of Stäger, however on pathogenicity and race specialization of C. purpurea, and other species of the genus, has yielded contributions of importance.

CLAVICEPS PURPUREA

Hosts

In the list of hosts of C. purpurea, the most common and widely distributed species of Claviceps and one with a very wide host range, are included those plants on which some kind of ergot has been found, but for which there is no experimental evidence to show the relation between the ergot occurring on them and C. purpurea . In cases where this species has been established as the causal organism by inoculation experiments, the host name is marked by an asterisk.

GRAMINEAE

Tribe Andropogoneae

Andropogon ischaemum[1]	145
" sorghum var. hemba hemba	159

Tribe Paniceae

Panicum miliaceum	145

---

[1] Cesati, Rabenhorst, herb. mycol. Ed. II. Cent. I, no. 38.

Pennisetum spicatum ?	143
Tribe Oryzeae	
Oryza sativa	237
Tribe Phalarideae	
Anthoxanthum odoratum	279
*Hierochloa borealis	54
" odorata	255
*Phalaris arundinacea	299
" canariensis	197
Tribe Agrostideae	
Agrostis vulgaris	145
Alopecurus agrestis	279
" geniculatus	145
* " pratensis	54
Ammophila arenaria	279
*Calamagrostis arundinacea	246
" canadensis	298
" confinis	298
" epigeios	35
" javanica	255
" neglecta	35
"Millium effusum	248
Phleum pratense	145

---

[1] Zimmermann (143) found ergot sclerotia on the heads of this plant and thinks that they probably belong to the genus Claviceps.

Tribe Aveneae

Aira coespitosa	299
" flexuosa	299
Arrhenatherum avenaceum	299
* " elatius	
Avena elatior	197
" pratensis	54
" sativa	279
Deschampsia flexuosa	255
Holcus lanatus	299
* " molle	299
Oats	

Tribe Festuceae

Arundo arenaria	55
" calamagrostis	145
Atropis distans	116
*Brachypodium pinnatum	70
* " sylvaticum	279
*Briza media	246
*Bromus erectus	248
" inermis	145
" mollis	145
" pratensis[1]	
" secalinus	54
* " sterilis	246
Catabrosa aquatica	54
*Dactylis glomerata	2279

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[1] Carruthers, W. In Jour. R. Agr. Soc. 10, pt. 11, 1874

Festuca arundinacea	25
" avena	35
" elatior	299
" gigantea	145
" nubigen	255
" pratensis	299
" rubra	35
" " var. lanuginosa	35
Glyceria fluitans	197
" nervata	172
" spectabilis	145
Koeleria cristata	5
" glauca	35
Melica ciliata	255
" uniflora	252
*Poa alpina	245
" aquatica	279
" caesia	246
* " compressa	54
* " concinna	248
* " hybrida	246
* " pratensis	296
* " sudetica	70
* " trivialis	248

Tribe Hordeae

Agropyron barbulatum	14
" devergens	6

Agropyron glaucum	297
" occidentale	93
" " X. A. repens.	190
" repens	197
" Smithii	190
" spicatum	b189
" tenerum	298
" violaceum	6
Asprella hystrix	189
Elymus arenarius	145
" " X Triticum junceum	113
" cadensis	22
" condensatum	36
" giganteus	237
" robustus[1]	
" striatus	189
" virginicus	189
Hordeum bulbosum	35
" distichum	299
" jubatum	189
* " murinum	37
" nudum	14
" vulgare	35
" " tetrastichum	25

---

[1] Halsted. Ia. Agr. Col., Dept. of Bot. Bul. 19. 1886

*Lolium italicum	279
* " perenne	279
* " regidum	248
* " temulentum	197
*Secale cereale	197
" montanum	35
Triticum coninum	14
" durum	145
" hiberni	279
" junceum	113
" repens	229
" sativum	299
" spelta	145
" turgidum	145
" vulgare	279

Unclassified

Ataxia Horsfieldii	255
Baldingera arundinacea	144
Limnochloa Baeothryon	145
Schenodorus inermis[1]	55

CYPERACEAE

Carex species	145
" stellulata angustata[2]	82

---

[1] In seed sample

[2] It is not known whether this is a true Claviceps as the attempts to germinate the sclerotia failed.

Cyperus species	145
Heleocharis multicaulis	145
" (Scirp) palustris	145
" uniglumis	145
Scirpus rufus	145

Taxonomy

Sclerotial Stage

Although the true nature of ergot was not known by early writers ergot is mentioned by many of them as is shown in the preceding history.

Lonicer (1565) mentions it under the name of Clavis Siliginis and speaks of its use. Thalius (1588) referred to it as "ad sistendum sanfuineum" and gave it a place in his book under the name of Secalis mater. Bauhin (1626), who cites the first two authors, called it Secale luxurians.

Munchhauses (1765), the first to consider ergot a fungus, called ergot sclerotia Clavaria solida. Baldinger (1771 gave it the name Secale dorutum. Schrank (1789] called it Clavaria clavus. Tode(1790) placed ergot in a special genus which he called Sclerotium. Paulet (1793) described ergot as Clavaria secalina. DeCandolle (1815) applied to it the name Sclerotium clavus.

Ascigerous Stage

The ascigerous stage of ergot, or *C. purpurea* Tul. was first described by Paulet (1793) under the name *Sphaeropus fungorum*, and then by Fries (1822) under the name *Sphaeria purpurea*. Schumacher (1823) called the same *Sphaeria entomorhiza* and *S. capitata*. Wallroth (1844) described it as *Kentrosporium purpurea* dn *K. mitratum*. These two correspond to the two Sphaeria species of Schumacher. Fries later (1846) applied the name *Cordyceps purpurea*. Tulasne (1851) called it *Cordiliceps purpurea* and finally (1853 *Claviceps purpurea*.

Conidial State

Fries (1822) first described the conidial stage of ergot under the name *Spermoedia clavus*. Leveille (154) in 1826 noticed that the ergot commenced with this soft covering (the sphacelia stage) and considering it to be a distinct fungus parasitic on the ergot, and proposed for it the name *Sphacelia segetum.*[1] Nees applied to it the name *Fusarium heterosporum* (Sacc. Syll. Fungorum, no. 2, p. 565. John Smith(236) and Quackett in 1841, published a description of the structure of the fungus in this sphacelial condition, as far as they were able to observe it. They thought it was an amorphous mass of small spherical cells, with a number of larger

---

[1] Spacelia is a word derived from the Greek and meaning gangrene; the same word in a secondary sense means mildew. We have the English work Sphacelate, which means to become affected with gangrene.

binucleate oblong cells scattered among them. It was supposed to be the immediate cause of ergot and Queckett gave to it the name *Ergotetia* abortifaciens, while Berkley and Broome (20) believed it to be a true Oidium and removed it to that genus under the name *O. abortifaciens*.

Ergot on account of the nature of its development, has been placed in at least three different families. First it appears as a hyphomycete in the form of *Sphacelia segetum* Lev., then the real ergot is produced which is known under the name of Sclerotium clavus D. C., This develops finally into an ascigerous state, Claviceps Tul., which belongs to the Pyrenomycetes. The fungus passes, therefore, during its life history through the types of not less than three families, according to the old classification of fungi.

Morphology

Sclerotium

Upon examination of a head of ergotized rye we find one or more of the rye kernels replaced by blackish horn-like bodies. Upon removing one of these it may be noted that its production has not materially injured the spike and that its growth has been confined to the flower from which it was taken. These ergot sclerotia, especially when small in size, resemble in form the kernels of the host on which they are found, except that they are more or less irregular. They are long, twice or three times as long and stout as the normal seed, extended, usually curved, somewhat angular, longitudinally corrugated, minutely granular and often slightly split both transversely and longitudinally, the cracks sometimes showing a reddish margin, and exposing the whitish interior substance of the sclerotium.

Externally, the ergot sclerotia are grayish-violet, sometimes dark or light violet or grayish-white, temporarily having a dusty appearance which is due to a waxy substance on their surface.

The interior of the mature sclerotia is hard, not always uniform in color, but usually white. Often there are in the internal tissue of the sclerotia distinct milk white grayish-white or bluish-white stripes. Although Kühn thinks that there can be no distinction between differently colored sclerotia, some have tried to classify them according to color as harmful and harmless sclerotia.

A faint, sickly odor of camphor is noticeable from fresh ergot. Its taste when raw is slightly bitter and nauseating.

In size, the sclerotia vary considerably depending first upon the size of the flower glumes in which they are produced, and second upon their member in a single head. The smaller the flowers are the smaller will be the sclerotia. In most cases they are one or two times longer than the flower glumes although they sometimes may become much longer. In rye they are one to three centimeters long and up to eight millimeters in diameter. Sclerotia from Molinia coerulea are four to six millimeters long and one to one and one-half millimeters thick; from Poa annua they are scarcely three millimeters long; from Poa pratensis they are never longer than six millimeters On Elymus canadensis they are almost if not fully as long as on rye.

Stroma

After having passed through the resting period, the ergot sclerotium, if put in a moist chamber or planted in moist soil will develop stromata. These stromata may all appear simultaneously or break through gradually. By the breaking through of the stromata the outer layer of the sclerotium is pushed up in an irregular form and finally pushed aside. At such points there appear globose, compact, white bodies which gradually in-

crease in diameter, usually showing on their surfaces droplets of a clear liquid. These bodies are the stromata which increase to about one-half millimeter in diameter and are then pushed up by their stipes which develop under them. The stipes develop very uniformly in moist chamber whereas in soil they grow just long enough so that the stromata will be on the surface of the soil. The shallower the sclerotia are planted, the shorter the stipes will be. The stipes are somewhat thicker and usually covered with white fibers at the bases and smooth above. The stipos are at first pale yellowish, later reddish, finally purple-violet colored or lilac above and lighter to nearly white at the bases, especially after the stromata are nearly mature. As a rule the stipes are uniformly cylindrical and slender, sometimes broadened and of spiral form; broader at the base and tapering toward the apex. Sometimes two stalks and their stromatal heads are grown together. In such cases, the stalks are abnormally shortened and thickened. Delacroix (51) reports a case where a germinating sclerotium of *C. purpurea*, instead of many stromatal heads, formed just a single but much larger one. The number of stromata depends largely on the size of the sclerotium. Kühn reports that as many as thirty-three stromata may be formed on a single sclerotium

The stromatal head at its base where it joins the stipe is not closely adnate but overhangs this as a free ring. The stromatal heads are almost spherical in form and vary in size up to 1.5 mm. in diameter. In color, they are at first light yellowish; later reddish flesh-colored to pale fawn. Their upper surface is uneven, slightly warty (verrucose) because of the projecting ostioles of the perithecia, which are found sunken throughout the entire surface of the sphaeridium.

The perithecia are egg or flask shaped, with the sharper point towards the ostiole. The little projecting mouths are the ostioles. The perithecia are filled with long, more or less curved transparent osci which are narrower at the base and apex and broadened in the middle. They spring from the base of the perithecium. The asci are surrounded by numerous sterile threads, paraphysees, which are somewhat thicker at their apical ends.

In the literature is mentioned that paraphysees are not present in Claviceps perithecia. However, in fresh material by the addition of potassium iodide two kinds of asci are recognized (62). The larger number of the asci contain spores, a smaller number have a granular consistency. These are the paraphyses and are distinguished by their contents and not so much by their form.

In each of the thin, colorless asci are found eight asco-spores, which evidently are set free by breaking of the ascus at the base. The spores themselves are very fine, long, attenuated, linear bodies and are usually somewhat curved, 50 to 76 µ long. According to Freeman (72) they are many septated, sometimes as many as sixty-two times. Güssow (85) working with barley Claviceps, found that osco spores have but three septa. Fyles (76) found this same number of septa in the ascospores of Claviceps from Zizania.

Sphacelium

The ascospores or the conidia of Claviceps when brought to the flowers of the susceptible host and given favorable conditions, germinate, and invade the young ovary. The growth enlarges forming a dirty white, soft and slimy mass as long as, or longer, than the glumes, and having on its upper surface a wound-like appearance. This stage in the development of Claviceps is called the sphacelia stage. The interior of this growth consists of irregular channels and holes extending longitudinally and transversely.

The whole surface of the Sphacelial growth including that of the channels and holes is covered by closely appressed elongated conidiophores, each one supporting a conidium. The conidia are formed continuously on these spore-bearing organs. The hyphae from which the conidiophores arise remain the same as those formed upon the germination of the ascospores. Closely connected with the formation of masses of conidia, is the abundant secretion of the "honey dew" previously described, which holds in suspension liberated conidia and which carries them out of the sphacelial growth. The conidia are very numerous, are spherical to sphaeroidal hyaline, and very small7 x 3.5µ

For a considerable time, little was known regarding the true nature of the sphacelial spores, in spite of the fact that their importance had long been recognized. Berg (19) considered them as spermatia in the sense of male fertilizing organs, but this conception was disproved by Kühn who showed that they were procreative cells - the "stylospores" of the ergot fungus. He applied the term "Stylosporen" and not conidia to the sphacelial spores of Claviceps typhina, because of the peculiar way in which they were borne. He thought that they corresponded fully to the uredo-spores of Uredineae. In his book (144) published shortly before his paper (145) Kühn referred to Tulasne's secondary spores as "Keimhörner".

Physiology

Very little cultural work has been done with C. purpurea and practically none with the other species of the same genus. The first man who studied C. purpurea under artificial conditions was Brefeld (29) He transferred spores of C. purpurea to bread which had been sterilized and soaked in a nutrient solution. The spores germinated readily, producing a rich growth and numerous conidia (sphacelia) typical in all respects to those developed on infected plants.

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The whole mass of bread, which measured eight inches in length and one inch in thickness, was permeated by the fungus. Labyrinth-like passages were formed in abundance and their surfaces were covered with conidia. In no cultures were there any sclerotia formed, even when kept for over six months. In his attempts to produce sclerotia the only thing Brefeld was able to obtain was a visible coloring of the fungous growth to violet, as observed in ergot sclerotia, but careful investigations showed that this was not to be considered in any way as indicating formation of sclerotia.

Engelke (62) grew C. purpurea on two different artificial media with the same results as Brefeld. He used nutritive solutions and hard media. The first consisted of 5 percent glucose, 0.5 percent ammonium nitrate, 0.25 percent primary potassium phosphate, and 0.125 percent magnesium sulphate. For nutritive hard media, he added 2 per cent agar-agar to the above. He also used ascospores of C. purpurea. The fungus grew well on both media, but in the nutritive solution the growth was somewhat better. In solid media it is more inclined to pass into what he called "Microsclerotia" which is especially favored by the lowering of the temperature. He kept the temperature between 15-25°C. Also in a solution containing 10 percent glucose and 5 percent crystal sugar (probably cane sugar) the fungus showed equally as good growth, while in 5 percent lactose it showed a weaker development of conidia. No gas bubbles were observed in any of the nutritive solutions used.

Brown and Ranck (33) grew C. paspali on bean pods. The fungus grew slowly throughout the pod, but did not show any signs of producing reporductive bodies.

Relation to light

It has been noted that the stromata of germinating ergot are positively phototropic and negatively geotropic, and that the intensity of the stroma coloring varies directly with the intensity of light within ordinary limits.

Pathogenicity.

The first inoculation with ascospores of *C. purpurea* was done by Durien (280) Tulasne made inoculations with *C. purpurea*, *C. nigricans*, and C. *microcephala*, using both ascospores and conidia. Kühn repeated the experiments of Tulasne with *C. purpurea*. Following the classical experiments of Tulasne many other workers have been able to produce the disease by artificial inoculation with both ascospores and conidia. Stäger in his study has made a large number of successful inoculations, from which he was able to establish some new species and certain specialized races. He also showed the host range of each.

LIFE HISTORY OF CLAVICEPS PURPUREA INRELATION
TO
PATHOGENESIS

Seasonal development of the disease.

The ascospores described in a prededing chapter are produced in great numbers, as we shall see later, and are carried in various ways to the flowers of the susceptible plant. When moisture and temperature conditions are favorable, they germinate within 24 hours. At the beginning of the germination, the spores swell and with the progress of germination light spots appear throughout their length, followed by a widening at certain points.

Sometimes these widenings are close to each other, and sometimes farther apart. Out of these swollen points on one or both sides of the spores there appear germ-tubes. The development of the germ-tubes on the same spore is not uniform; single germ-tubes may have reached a considerable length while others are still very short. Soon these germ-tubes grow into long, branched hyphae, forming mycelium of the sphacelial stage. This takes place in spring just when the host plants are blossoming. The young mycelium coming from the ascospores forms numerous conidia at the ends of their lateral branches. The conidia which are formed apically one at a time arrange themselves sidewise on the stalk. They do not adhere in a chain but each new conidium pushes the former aside and they remain in parallel groups until jarred apart. Sterigmata are not to be differentiated. This uniformity becomes more marked when conidia are formed on nutrient media, as a result of immediate germination of the conidia. The conidia, as already mentioned, are themselves capable of immediate germination and of infecting plants if carried to them when they are in blossom. The germinating conidia may send out a single tube at one or at each end within six hours, if conditions are favorable. The newly formed mycelium soon becomes rounded at the end, then continues to enlarge into an egg-shaped conidium. Two or more conidia may be formed at the same time. In such cases they lie length-wise on the side of the mycelium so as to make room for new conidia. The formation of numerous conidia, however, is not always common.

The nuclear division in the sphacelial stage goes on very rapidly (109) Each nucleus divides; part of it passes into the newly formed conidium; the other part continues to grow and re-divides. Conidia may be formed also on the side of the promycelium without being preceded by branching. A short stalk only being projected on which the conidia are borne.

A cross wall is formed between the promycelium and the stalk. The newly formed conidia are like their parents but slightly smaller. The ability of this fungus thus to form secondary conidia on promycelium is important in that it enables the first conidium when not on proper substratum, simply to form with sufficient moisture numerous new conidia, one of which at least may possibly find its way to a rye plant or other grass host and so further perpetuate the fungus. In its further development the sphacelial growth shows a decided tendency to spread itself upward before it has attained its full development at the point of infection. When this is reached, as a rule, the ovary and often even the anthers are covered with the sphacelial growth. Occasionally parts of the ovary or anthers in the midst of the fungous growth or above it are preserved. Such is the case when the ovary has been more or less developed before the infection took place, or when the spores, though they have been brought to the ovary at an early time, because of the dry weather have been retarded in the formation of the sphacelial stage. In such cases the formation of sclerotia may fail entirely and the rye kernel, in spite of the first stage of infection, may yet be formed, though in an imperfect form. However, if the development of such sphacelial stages be favored by moist weather sclerotia may still be formed, which are crowned by the more or less developed seed. It may also happen that such a kernel retains a normal appearance but actually is a sclerotium, the fungus having failed in its destructive work in the attainment of its full development. Such a partial development and preservation of the starch forming kernel tissue between the sclerotial tissues is a phenomenon of very rare occurrence.

Closely connected with the formation of a great number of conidia in the sphacelial state is the abundant secretion of "honey dew" which holds in suspension liberated spores and carries them out of the sphacelial growth. Since the production of "honey dew" on the rye heads is facilitated by the moist weather (heavy fog, etc.) the farmers have been inclined to think that ergot was caused by weather conditions. Because of the peculiar odor of this exudate, which is accentuated by moist atmosphere so that it is noticeable for long distances, it has been said that the "stinking fogs" were the cause of ergot formation.

There exists a great difference of opinion concerning the nature and origin of the honey dew. Bonorden (26) noticed, on heads infected with ergot, the secretion "honey dew" which he says is without doubt secreted by the nectries as a result of the stimulation caused by the fungus. In his later work (27) he says "The spores are covered by a liquid having a sweetish taste," but he does not discuss the origin of the same. Kühn considered it as having no connection with the host and pointed to the fact that the liquid persists after the parasite has destroyed the internal parts of the flower, and that at that time the secretion is even richer than at the beginning. It keeps pace with the progressive growth of sphacelial hyphae and only begins to decrease after the latter has reached its highest point of development and the formation of the sclerotium has begun. It seems, therefore, that the hyphae of the sphacelial stage have the property of secreting a special substance before the beginning of sclerotium formation. This slimy secretion of the hyphae appears at the same time as the formation of spores.

Kühn, thinks, however, that there is not necessarily a connection between the secretion of the dew and the formation of spores, but that both processes are connected with the formation of sclerotia. Accordingly the spores liberation in the liquid is accidental, even though it is of great importance for the drawing out and dissemination of the same (145) To Wilson (299) it seems a mistake to suppose that the fliud is exuded by the fungus. The quantity is so large and the flow so continuous that absorption from the air seems the true explanation. Sorauer takes Kühn's view and thinks that the "honey dew" is secreted by sphacelial hyphae.

While the development of sphacelial stages extends upwards, a wholly different process takes place at the base of this growth. Here the mycelial threads increase in number and send out numerous branches which together with the swelling of the hyphae themselves result in a considerable thickening of the growth. At their growing points the threads are filled uniformly with protoplasm. On their older parts, on the other hand, there appear lighter zones, and through these an apparent tissue formation brought about by the formation of crosswalls at each of these lighter zones. In the thickened threads at this time there are formed numerous oil drops, such as occur later in the tissue of the perfect sclerotium. During this building of mycelial threads the structure of the internal part of the fungus is markedly changed. Some of the thread ends grow on the outside forming a covering of closely applied threads which lie parallel to each other. These neither thicken nor form oil drops. Their contents become clear and uniform, soon turning reddish, then violet colored. This coloration begins at the base and proceeds upwards, as did the mycelial growth preceding the formation of the sclerotium. When the sclerotium has

reached its full development it dries up into a brownish mass, forming the so-called "cap" or "tip" which crowns the sclerotium. Although "tips" are always formed, a great number of them fall off later. The color of the sclerotium is usually violet, but it may become darker or remain lighter, or even grayish white.

The sclerotium while still on the plant is cartilaginous. Later, upon drying, it becomes very hard. We have in it the resting mycelium of Claviceps which is a typical sclerotium

The time necessary for the formation of the sclerotium depends upon the weather. In dry weather the first signs of sclerotia formation appear about fourteen days after the appearance of the first "honey dew", while in moist weather, which favors a rich mycelial growth and rich secretion of "honey dew" the formation of sclerotia may begin as early as a week after the appearance of "honey dew".

When the sclerotia are ripe, usually at the time of harvesting, they either fall to the ground immediately or, after being stored with the grain find their way back to the fields with the seed. In the fields they remain in a dormant condition until spring when they resume their further development. The length of the resting period depends upon the host; upon the particular species of Claviceps; upon the condition of the sclerotia, and also upon the weather conditions. According to Tulasne and Kühn at least three months are necessary for the full ripening and resting of the sclerotium. Ergot (C. microcephala) from Phragmites, planted in January germinated in March after fifty-nine days. (C. purpurea) from rye planted in January, according to Kuhn (145) germinated in April, after ninety-six days. The same from Molinia coerulea planted in January germinated in April after ninety days. In nature the ergot of Phragmites germinates later than that of rye. The further development of the sclerotium which usually takes place in late spring and early summer just as the cereals and grasses are

heading, consists of the formation of stromata as described in a preceding chapter. These stromata are ripe when their color begins to change into purple violet and their stalks begin to lose their turgidity. The latter condition occurs first at the progresses base and upward. At this time there are formed in the numarous perithecia in each spheridium a great number of asci, each containing eight spores. These apores are shot out from the perithecia and some find their way to susceptible plants, where they germinate if conditions are favorable, causing infection again and thus completing the life history of the fungus.

Production of spores.

Both conidia and ascospores of Claviceps are formed in great numbers, the former in the sphacelial growth and the latter in the stromata. If the cloudy, sticky, "honey dew" is examined microscopically it is found to be teeming with millions of small ellipsoidal hyaline conidia. When it is considered that the "honey dew" is secreted in abundance for a considerable period of time, it is realized the very great number of spores produced in each infected flower.

The ascospores are produced also in considerable number. It was estimated by Wilsen (299) that from a sclerotium produced on Glyceria fluitans one-twentieth of an inch in diameter, contained about 3,000 perithecia, and it is known that a number of such stromata may be formed on one sclerotium. Kühn (145) states that a sclerotium with over fifteen stromata will produce over a million ascospores.

Viability and longevity of sclerotia

The evident function of a sclerotium is the resistance of unfavorable conditions, such as dry or cold weather or both. Just how long a sclerotium remains viable is not known with absolute certainty since the results obtained by various men are conflicting. Tulasne states, as a result

of his experiments, that if the sclerotium does not produce the stromata during the first year after it has fallen to the ground, it loses its viability. Early workers who studied ergot did not know that the ergot sclerotium retains its germinating power during one year if it is not dried out completely. In order to test this Rostowzew (214) undertook the following experiment. A number of sclerotia from rye were gathered in August and kept in a dry laboratory. Other sclerotia were placed in sand in a shallow pot and placed in a cold room with winter temperature of 0°C. and lower. The sand was moistened and later watered two or three times. In January the following year it was found that the sand and the sclerotia on the surface of the pot were entirely dry. During the remainder of the experiment the second lot of sclerotia were placed in pure sand in a dish and kept constantly moist. In February most of the sclerotia that during the whole experiment were deep in the pot germinated, whereas those that were near the surface of the pot and those kept in the laboratory and thus exposed to drying failed to germinate. The same experiment was repeated during the following year with sclerotia from *C. purpurea* obtained from various grasses and *C. microcephala* from *Molinia coerula* and yielded similar results. Lutz (165), on the other hand, reports that ergot sclerotia from *Psamma arenaria* harvested in August 1902 germinated in March, 1904, and also later in May and formed a reproductive apparatus similar to that of *C. purpurea*. Zimmermann (304) found, contrary to the observations of Rostowzew, that dry season or the dry preservation of ergot in bottles until planting time did not affect its germinating power. Working with ergot sclerotia, Zimmermann established the following facts:

1. Sclerotia germinate even during the second year after their formation.

2. Sclerotia, which failed to germinate the first year, even

when favorable conditions are furnished, are also capable of germinating during the second year.

3. The sclerotia that have dropped in the field germinate at the same time as do sclerotia of the same year which were planted later.

4. The development of sclerotia is markedly influenced by external conditions.

5. Rotted sclerotia often prove to be capable of germination.

6. Parts of sclerotia can also germinate.

Viability and longevity of conidia

Conidia of Claviceps have been known to retain their germinating power for over ten months and they may remain viable for even longer periods. Stäger's experiments in this connection are most important and interesting. He used conidia from sclerotia, gathered in Russia, in July and August 1911, and which still had the remains of caps on their tips, were still somewhat sticky, and had a distinct "honey dew" odor. The sclerotia were kept in the dark and over lime. On February 25th, 1912 he tested the viability of the still normal and fresh appearing conidia from the above sclerotia in hanging drops and as expected found them viable. On April 27th, 1912, blossoming plants of Anthoxanthum odoratum were inoculated with such conidia. at least nine months after the sclerotia had been gathered. On May 10th he observed a slight secretion of "honey dew" on the inoculated plants. On May 14th, the dew appeared in great quantities and sclerotia were formed later. On July 5th, 1912, he inoculated rye plants with some of the same conidia and secured infections. This shows that the conidia of C. purpurea retained their germinating power even after ten months. This fact was first demonstrated in 1858 by Bonorden (26), who

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showed that the dry "honey dew" still contains conidia capable of germination, but Stäger (256) was the first to demonstrate the same by inoculation experiments.

Dissemination of spores

Dissemination of conidia

Various factors are known to take part in the dissemination of the conidia found in abundance in the "honey dew". The secretion of "honey dew" continues for a considerable time, thus giving a chance for many different agents to take part in the dissemination of the spores. Winds during the sphacelia stage are especially important, as any motion of the heads, loaded heavily with dew, will bring them in contact with other healthy heads. The spores are spread in this way in a horizontal direction. This has been experimentally tested by Bonorden and confirmed by Rose. Rain helps also in spreading the conidia.

Probably the most common method by which the conidia are spread is by insects. As early as 1847 Leunis (153) mentions that a certain beetle (*Cantharis melanura*) visits in great numbers the infected heads for the "honey dew". Kolaczek (139) makes the same statement in his book. Stäger made a careful study of the relation of insects (a list of which he gives for certain hosts[1]), while visiting the infected plant for the dew, become loaded with conidia which they carry to healthy plants. The leaf louse, so commonly found on rye usually on all parts of the heads, because of their sweet secretion, attract many insects. These insects, when coming after the secretion of the louse during the period of anthesis, may carry the conidia and spread the infection.

Mercier (173) found that *Sciara thomae* L. visits very often *Lolium perenne*. He found sphacelial spores on this insect, in its digestive organs, and later uninjured in the excretions of the insect. He concludes

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[1] See list of insects below.

that there are two ways in which insects spread these conidia: (1) by carrying them on the exterior of their bodies, and (2) by sucking in along with the dew in a great number of spores which are excreted again uninjured on other plants. Tschermark thinks that ants may also spread the "honey dew" to uninfected plants. According to Sorauer, there are (239) special insects which visit each plant. He thinks that *Molanostoma mellina* and *Rhagonycha* are the most common and most important of these.

The following is a list of insects reported by Stäger and others that help in the dissemination of Claviceps.

Amblytheles subsericans	2
Ants	2
Anthomyidae genus	1, 2,
Anustronyche abdominalis Fbr.	
Brachytropsis calaratus	
Cantharis melanura	
Cheilosia species	?
Coccinella quinquepunctata	2
Coccinella septempunctata	2
Dilophus vulgaris	2
Dolorus pratensis	
Egeria Pararge	
Eurygaster Maura	2
Hylemyia sp.	
Leaf Wasps	
Leptis tringaria L.	
Lissonota cylindrator Vill.	
Lonchaea (fumosa ?)	1, 2
Lucilia sylvarum	2
Melanastoma mellina	1, 2,

Note. 1 = Pollen eating insects
2 = Honey dew sucking insects.

Miris holsatus	2
Melithreptus mentastri	1, 2
Mimesa Dahlbomi	
Ophyra anthrax Meig.	1, 2
Pipicella virens Fbr.	2
Platycheirus peltatus	2
Podabrus alpinus	
Pompylus viaticus	2
Pollenia vespillo Fb.	2
Rhagonycha fulva	2
Sapromyza sp.	
Sapromyza apicalis	
Sapromyza quadripunctata	1, 2
Sarcopha nigriventris or depressiformis ?	1, 2
Sarcophaga species	
Sciara species ?	2
Sciara Thomae L.	
Tachina (Genus x Species ?)	
Tetanocera ferruginea	
Tropicoris rufipes	
Vespa	2
Wasp	
Apis mellifica	2

Of all these insects only Melanostoma mellina and Rhagonycha fulva are commonly found on a number of plants, while the others are common only on certain plants and are considered less important in the spreading of Claviceps than the first two.

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Dissemination of ascospores

Practically all men except Stäger agree that the asco-spores are shot from the perithecia with great force and are thrown for a considerable distance. Stäger, basing his conclusions upon numerous experiments with various species of Claviceps, holds that the ascospores are not shot suddenly from the asci but slowly exude from the perithecia. He points out also that ascospores cannot be carried by wind because the stromata are completely covered with a slimy layer. During his numerous experiments he observed many flies visiting the sphaeridia of the germinating sclerotia. Another argument which, according to Stäger, helps to prove that insects spread ascospores is the fact that usually the single plant on the edges of the fields, which are usually visited more frequently by insects, are most commonly infected with ergot. The same is true for fields lying near woods where the number of insects is greater. The higher humidity here may also be a factor in this case.

According to Rolfs (261) C. paspali and C. rolfsii ascospores are disseminated largely by beetles, mostly of the family Carabidae. Engleke, on the other hand, showed conclusively that when specimens kept in a moist chamber or exposed in a glass jar, are exposed for a short time to sunlight and their stromata touched with a platinum needle, small clouds of shining spores are discharged. These spores may be thrown for a distance of about six centimeters. This tends to show that the spores do not ooze out from the ostiole of the perithecia but are shot out. Wilson (299) observed that while some of the ascospores were shot out with great rapidity for a time from a papilla here and there, other spores exuded out gradually on the surface. What the cause of projection may be is only conjectured. The conceptacles and the papillae seem to be filled with a brown jelly. The

rising of these papilla from a previously flat surface shows that a growth is going on and, consequently, pressure is increasing in intensity, so that when the ripe heads are exposed to a certain temperature or to other forces, the tension is brought to a crisis and the spores are projected by elastic pressure. Necessarily when this pressure begins to abate by the relief which follows the continued discharge, the spores are not acted upon by so great a force as at first. This may explain why the last spores instead of being shot into the air are merely pushed slowly to the surface. Indeed, it is almost certain that a great many spores are never ejected at all, but perish within the decaying stromata.

The liberation of the ascospores takes place in the following way. On the ostiole of the perithecium there appears a light drop, from which the spores come singly and very slowly. Finally the spores are thrown out, always toward the light and at a distance of two to eight centimeters. As a result of the phototropic rotation and bending of the stipe, one part of the head will be exposed to the light, then another, the dischare taking place always at a point directly facing the light.

The further dissemination of the ascospores is brought about, according to Falck (64) by air currents due to change in temperature, The Claviceps stipe functions in increasing the space for the falling of the freed spores thus affording more chances that they may be taken up by the air currents and carried farther away. If the stromatal heads were but a short distance above the soil surface, then only a small number of the ascospores will be disseminated.

Size, weight, and surface area of the spores play an important rôle in their dissemination. *C. purpurea* ascospores have, in ~~their dissemination~~.

relation to their weight, a surface area seventy times greater than that of Ascobolus spores. The energy necessary to transport the ascospores is, therefore, only one seventieth of that required to carry away the Ascobolus spores, not taking into account at all the fact that they have only one-five thousandth part of the weight of the latter.

By numerous experiments, Falck showed that the above factors are operative in the field. He proved that insects, rain, and other climatic factors are not necessary for the infection of rye by Claviceps. He showed that as the temperature of the ground at any time is higher than is that of the surrounding air, there ia always a constant falling of temperature and, therefore, an air current which is sufficient to carry the ejected spores to the height of the heads, where under favorable climatic conditions, of moist air and quiet weather they will cause infection.

Method of infection

The exact method by which the fungus penetrates the ovary is not known. It seems, however, quite evident that it does not penetrate through the glumes, as indicated by the smaller degree of infection in varieties of plants that have their glumes closed during the period of flowering. Engelke found that infection was successful only before the flower was pollinated and before the pollen grain had sent out its germ tube. At this stage the spore or conidium that has found its way to the flower can germinate in the nectar of the flower and then extends into the cavity of the ovary around the ovule, where it begins the transformation of the ovary by the vegetative processes of the mycelia. This according to him, explains the formation of the sclerotia in the place of the ovary instead of at the base of the kernel as was supposed at first. Infection through the "spaltoffnungen

des Fruchtknotens ist ausgeschossen", according to him.

Period of incubation

The time which elapses between infection of the heads and the first appearance of "honey dew" which is the first positive evidence that infection has taken place, varies considerably with environmental conditions, also with the stage of flowering of the host. Dry and cold weather is likely to retard the appearance of the honey dew, while moist and hot weather as is well known will hasten and favor an abundant secretion of the honey dew. In plants infected before anthesis, first signs of infection appear later than under other conditions.

The period of incubation varies also with different species of Claviceps. For C. purpurea it is from seven to fourteen days; in cold weather, usually about fourteen days. For Claviceps on Poa it is only five to six days; C. wilsoni, eight to thirteen days; Claviceps on Lolium eight to eleven days; C. microcephala, ten to sixteen days. While these periods give an idea of the relative length of the incubation period, they should not be taken at their face value, because all of these data have been secured at different times under different conditions. It seems likely that if inoculations had been made at the same time and under the same conditions with various Claviceps species and biologic races the results might have been more similar.

Time of natural infection

Infection in nature, as well as under artificial conditions takes place usually during the flowering period of the host. There is still, however, some difference of opinion as to the particular stage of blossoming during which the plant is most susceptible to infection. Engelke (62) found that infection with conidia was successful only before the flower was pollenated, that is, previous to the production of the pollen tube by the

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pollen grain. At this stage the spore or conidum can germinate in the nectar of the flower and then extend into the cavity of the ovary and around the ovule.

Stäger (248) on the other hand, obtained infection by artificial inoculation with honey dew from Anthoxanthum odoratum even when the plants were in "Verblüen". This tends to show that infection may take place even after fertilization. Tschermark (274) observed that, in rye, infection takes place in pollenated as well as in unpollenated flowers. The failure of florets to become pollenated offers a greater chance for ergot infection both in rye and in barley as the glumes then remain open for a longer time. No sclerotia are formed on plants infected after the period of blossoming has passed Stäger (248) showed also that plants inoculated with ergot three to four days before flowering become infected very readily. He thinks, however, that infection does not take place immediately but that the conidia preserve their germinating power until the flowers open and then germinate and cause infection in the usual way. It may be true also that the spores germinate immediately and then continue to grow if there is sufficient moisture, produce new conidia, and then infect the plant when in full blossom.

Source of inoculum.

From the previous discussion it is apparent that the original source of infection is the germinating sclerotium. On plants infected with ascospores, masses of conidia are soon produced. These are also able to cause infection and again produce new conidia. This process is continued as long as there are susceptible plants in blossom. Only a few infections with ascospores are sufficient, therefore, to cause an epidemic, if other conditions are favorable.

In one case, C. purpurea biologic race on Brachypodium silvaticum, whose sclerotia germinate long before the flowering of the host, B. silvaticum, the fungus must pass first to Milium effusum, which is in blossom at the time the ascospores are discharged. On this host it produces the sphacelia stage and then these conidia are carried over to B. silvaticum where they cause new infection.

Overwintering of the causal organism

All Claviceps species overwinter in the form of sclerotia, the function of which is to carry the fungus through unfavorable conditions. Even though conidia, if kept dry and in the dark, preserve their germinating power for over ten months, it is very unlikely that in nature such conidia would survive for any length of time. There is, however, no experimental evidence bearing on this point.

A method of developing the Claviceps stage

It is often desirable to be able to produce the ascigerous stage of Claviceps from ergot sclerotia for class use or experimental purposes. Different workers have accomplished this in various ways, but Whetzel and Reddick (294) describe a method with which they were very successful. The following is a description of it. About the middle of August they gather fresh sclerotia from the heads of rye or other infected plants. These are then enclosed in ordinary screen wire and put on the ground under a tree. The sclerotia are not disturbed until about April 6 the following year when they are taken to the laboratory and placed in moist sand in a covered stender dish and kept at room temperature. About two weeks later the first signs of germination begin to appear. By the middle of May a majority of the stromata will be developed and a great many of them will contain mature ascospores. The time of appearance of stromata may, however, vary slightly for different sclerotia.

CLIMATE AND OTHER FACTORS IN RELATION TO THE DISEASE

Climate has a very marked effect upon the amount of ergot infection. In dry seasons there is usually very little ergot infection, but during wet seasons, especially when there is considerable sunshine during June, it develops abundantly. Warm and sunny seasons are very favorable for ergot infection in the northern part of Europe, according to Müller (185). Ravn (208), who studied the relation of weather to the degree of infection of various fungi, writes the following for ergot. "For C. purpurea the temperature condition does not seem to play any rôle. On the other hand, there exists a close relation between the degree of ergot infection and amount of sun during June. With the exception of the year 1894 the rye remained free from ergot in years with a dry June." Rev. Canon Du Port (58) reports a considerable quantity of ergot among the marshland wheats in the year 1879, in which the summer was abnormally wet and sunless. Rostrup (216) states that in 1893, because of the dry weather that lasted during the time of blossoming, there was only a very small degree of infection, while the wet season in 1894 favored the development of C. purpurea so that it occurred very abundantly. In dry and warm air and soil the flowering takes place very rapidly (274) often wholly within the blade (this is true primarily for barley). The possibility of infection under such conditions, therefore is very small. On the other hand, sudden heat on moist soil causes rapid heading and the coming out of heads long before the flowering. It also causes a wide opening of the glumes. Cool weather prolongs the flowering outside of the blade and so favors infection. Anything that prolongs the duration of the flowering period and the time that the glumes remain open also favors ergot infection. For this reason ergot is found more commonly on isolated plants, on those in poorly over-

wintered fields, and on those on the edges of fields. It is also found on late shoots, whose glumes, because pollenation fails, remain open for a week or more.

The weather not only affects the degree of infection but also the amount of ascospore formation and the extent of ascospore dissemination. The ascospores are thrown out copiously in bright, warm weather, are lifted up from the damp places where they are produced by ascending atmospheric currents and are carried by the wind. Damp weather is necessary for the ripening of the ascospores and dry weather for their dissemination. Even though such damp and then dry weather has brought numerous spores into the atmosphere in July and August, if the season has not been sufficiently damp to make the grasses taller and draw up late spikes, there will be less ergot because of the smaller number of flowers to be ergotized. A season which is at once favorable to Claviceps and to the production of late flowering grasses is, according to Wilson (299) required for the largest development of ergot in Scotland. Edwards Carroll (37), contrary to the views of other authors, says that ergot is rare when the season is wet, frequent when it is dry. This, he explains, is due to the fact that in Ireland, where he made his observations, the moist atmosphere is enough for the germination and successful establishment of the fungus, while rain would wash the spores off the plants and a superabundance of water would be unfavorable to their growth. On the continent, where the atmosphere is dry, rain may be necessary for its growth, according to Carroll.

The topography of the field, the drainage, the shading, the soil conditions and the time of planting have also been associated by some men with the degree of ergot infection. Pammel states that ergot flourishes particularly well on rich soil and in warm, damp seasons (190). It is a well known fact that ergotized grasses are more apt to be found in the low

damp ground than where the soil is dry, and it is the wild grasses along streams that are most severely ergotized (87) Kühn (145) thinks that the occurrence of ergot does not depend upon ghe soil composition or the topography of the land. Luerssen (164) agrees with Kühn and adds that moist soil favors the development of ergot. Anthoxanthum odoratum is most severely ergotized in shady places, in woods, or on the north border of woods. Nardus stricta is ergotized in woods and also on open healthy moors where no shadow falls upon it. Phalaris arundinacea has been found ergotized mostly near the edge of rivers. Late sown rye (245) is also supposed to be more heavily infected with ergot than early sown rye.

VARIETIES IN RELATION TO THE DISEASE

Flowering with closed glumes, uniformity in time of flowering, and rapidity of flowering are three important factors affecting ergot infection. Varieties possessing any or all of these characters are less infected by ergot than are other varieties. Varieties less inclined to remain sterile are infected with ergot to a lesser degree. Tulasne first observed that cereals and grasses, Arundo phragmites for instance, which under the Parisian climatic conditions remain sterile, are frequently attacked by ergot.

At a very early date Wilson (299) came to the conclusion that there may exist a relation between the length of the period during which the glumes are open and the amount of ergot infection, but he was not quite sure about this. "Still there is reason", he says, "to suppose that greater mechanical exposure is a large part of the explanation of greater liability to ergot. The species of Bromus which grow here open very little for fertilization, and soon close very tightly and are never ergotized." Henning (97) noticed that on six-rowed barley the ergot sclerotia appear mostly on the side rows and comparatively seldom on the flowers of the middle rows. This was later explained as being due to the fact that the spikelets on the

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side rows are more apt to be open during fertilization than those of the middle rows. Among the two-rowed barley, the variety nutans very often has ergot and the variety erectum, on the contrary, very seldom. This condition apparently bears some relation, according to Henning, to the fact that open flowers in six-rowed barley, as well as in the variety erectum of two-rowed barley, occur comparatively seldom. He also emphasised the fact that infection with ergot presupposes open flowers. These observations of Henning were confirmed and extended by Tschermakr. The glumes of the two, four, and six-rowed hulless barley varieties are relatively wide open, hence their inclination to outside pollination and ergot infection. Hannchen barley, which has more open flowers than other varieties, is also more susceptible to ergot (158) Rapidly flowering barley often has open flowers and is, therefore, more exposed to infection (274)

The glumes of wild rye remain open for longer time because the anthers do not discharge their pollen all at once, but the latter are set free very gradually and only after a long drying out. On account of this the wild rye depends more upon an outside pollination than does the cultivated rye. With this mode of flowering, it is more likely to remain sterile and therefore more exposed to the spores of ergot. This is also true for the F_1 generation of the perennial hybrid Secale montana x Secale cereale, as well as for the greater part of the segregation products of the latter generation.

The spikelets of late rye remain open longer and they also lose the elasticity which enables them to draw back the glumes, the latter remaining in this position during dry and hot weather even after fertilization has taken place, and regaining their elasticity only after the coming of rain. Meanwhile the flowers may become infected.

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In regard to uniformity of flowering, a pedigreed strain which exhibits uniformity in growth and blossoming suffers less from the disease than do other varieties. The factor of rapidity plays a part as illustrated by the rapidly flowering barley which often has open flowers and is, therefore, more exposed to infection (271)

The height of the variety seems also to have some influence upon the degree of infection. The nearer the heads are to the ground the more they are ergotized.

Anderson reports that the variety "Little rye" is not materially injured by ergot.

CONTROL MEASURES

A considerable number of control measures for ergot have been recommended at different times, a great many of which are either impossible to apply on a large scale or are ineffective. There are also some control measures which, if applied properly and at the right time, may be of considerable help.

Sanitation

The earliest control measure recommended and still applied is the gathering up of the sclerotia while they are still on the plants in the field. In this case the sclerotia can be sold to the druggist for a good price.

Deep plowing of the fields on which infected crops have been grown and deep planting of the seed are also recommended for controlling ergot, the idea being that the sclerotia contained in the seed or those that have fallen to the ground from the previous crop will be buried deeply and not be able to send out their stromata.

Early harvesting, which would tend to lessen the number of sclerotia which fall on the field, is also recommended.

Burning over of heavily infected fields or of the land on which ergot has been allowed to mature will destroy a large number of the sclerotia.

Destruction of all susceptible grasses in the vicinity of the cereal fields, or mowing them when in blossom, is a very useful practice in the elimination of ergot. In some cases, this has to be done several times during the season in order to entirely prevent the formation of sclerotia.

Clean seed

Only sclerotia-free seed should be used. Separation of the sclerotia from the grain by various means is used very widely. Screening, sifting, fanning, and sedimentation of the seed are used for this purpose. Weinziere (292) found that by the use of special machines for cleaning and grading of grain the amount of ergot can be decreased to 0.17 per cent. In rye with 1 per cent of ergot the amount of ergot can be decreased without difficulty to 0.06 percent and even less, according to Hotter (107) While, in this way, we may decrease the number of scelerotia in the seed it is not possible to separate them entirely.

The separation of sclerotia by sedimentation is the most effective method for obtaining sclerotia free seed. Müller (185) first used this method and he was the first to apply to it the term sedimentation. He used a solution of 30 to 32 percent of common salt or 37 percent of potassium chloride for the separation of ergot. The grain having a higher specific gravity than the ergot remains on the surface and can be easily taken out. The grain is then washed with water and rapidly dried. He recommends the use of potassium chloride instead of common salt because it does not injure the seed and, besides this, it can be used as fertilizer after the treatment.

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Jacewski recommends 30 percent salt solution and was the first to work out a practical way of using Müller's method. By this method the grain containing ergot is placed in a specially perforated vessel, the vessel is then dipped into the container with the solution, and the grain stirred up in it with a small wooden shovel. After the grain becomes wet, it drops to the bottom of the vessel while the ergot sclerotia always remain on the surface and can be easily separated. The seed is then washed with pure water and spread on a floor to dry. The sclerotia obtained in such a way may be sold to the druggist.

Soil treatment

Several attempts have been made to control ergot by applying chemicals to the soil but the results are not very promising. Griffiths (79) recommends top-dressing with iron sulphate (from fifty to one hundred pounds per acre) of all land liable to the attacks of Claviceps. McAlpine (170) recommends the same treatment.

Wütherich (303) showed that iron sulphate in the quantities in the quantities given above does not in any way affect the germination power of sclerotia. He showed that ergot sclerotia could germinate in 1.4 percent iron sulphate, and that at least a 13.9 per cent solution was necessary to destroy them. Both of these concentrations are too strong to be applied in the fields. Wütherich also did a considerable amount of work on the effect of various chemicals on the germinating power of Claviceps spores and conidia, but since the results are of no practical importance they are not included here.

Seed treatment

Thorough drying of the seed and dry summer weather will, according to Rostowzew, kill the ergot sclerotia. Reliable work indicates, however, that this is not true.

McCarthy recommends soaking the seed for eight to ten minutes in water heated to 135° to 140°F., after which the seed is dried and planted.

Cultural methods

Crop rotation is found to help considerably in decreasing the amount of ergot infection. Clover, sugar and cow beets, potatoes and other crops not susceptible to ergot should be introduced in the rotation.

As ergot infection is said by some to be favored by moist soils with underground water, good drainage is also recommended for prevention of ergot.

As mentioned before, a rapid and unfform blossoming of the cereals will prevent infection on a big scale because of the short period of infection. The above may be brought about by applying all rules of rational farming: good drainage, deep and good cultivation, normal and not one-sided application of manure and fertilizers, proper rotation good seed, and planting with a drill. Early and late varieties should not be planted close to each other, because the late sown crop is likely to become infected heavily. All these measures do not, however, prevent the appearance of ergot but hinder its spread.

Cereal varieties that stool little should be used, for varieties which do not stool will be in blossom for only a comparatively short time, and the shorter the time of blossoming the smaller the possibility of infection.

Resistant varieties

Resistant varieties, where practicable, should always be used. The variety "Little rye" is reported to be less susceptible to ergot. (5) Six rowed barley and the erectum varieties of two-rowed barley are also

reported to be attacked only seldom by ergot.[1]

Because of the wide host range of ergot and considering its equally wide adaptation to many unrelated genera "Theoretically," therefore, there is very slight probability for plant breeders to find a great difference among races of rye, barley, and wheat in their susceptibility to this fungus. The great difference between rye, barley, and wheat in their degree of infection by ergot (the two latter are very rarely attacked by ergot) is evidently connected with the different modes of flowering of these cereals. Rye usually flowers with opened glumes, wheat and barley with clo closed glumes, and the closed mode of flowering prevents the two latter from being infected by ergot" (28).

Biffen (23) communicated the curious fact that there occurred among the F_2 hybrids of Rivet wheat (T. turgidum) with several varieties of T. vulgare some plants which were attacked by ergot, although the parent forms had never been seen to be attacked by this fungus. Biffin explains this phenomenon as a result of the combination of two Mendelian factors for susceptibility to ergot. These are separated in the parents and in separate forms cannot produce the susceptibility to ergot of wheat, which results when they are combined in the offspring.

Vavilov (293) gives a different interpretation to theabove fact, for which he finds support in a similar case reported by Rimpau. In 1891 Rimpau noticed that in the same hybrid Rivet T. vulgare there appears in the F_2 generation some sterile plants. In consideration of this fact

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[1] See the discussion of this subject under "Varieties in relation to ergot infection".

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reported by Rimpau, Vavilov says that "sterile plants of cereals as is known flower usually with open glumes, remaining many days in this state, and commonly are badly attacked by ergot. The sterile plants of F_1 of the hybrid of wheat and rye, for example, are severely ergotized." He concludes, "evidently the same fact of appearance of sterile plants was observed in the experiments of Professor Biffen at Cambridge, and, as might be supposed, these sterile plants were attacked by ergot. Vavilov's explanation of the ergotized hybrids makes the possibility of obtaining resistant strains by breeding seem slight. It leads us to think that there may be an absence of Mendelian characters of resistance and susceptibility. Still it may be possible that varieties with closed glumes can yet be obtained by this method. From a practical standpoint, such varieties serve the same purpose as varieties with resistant characters.

Claviceps balansioidis Möll. on Panicum (Echinochloa) (180)

The mycelial hyphae of the fungus practically cover the whole spikelet or even two neighboring spikelets. On the glumes there is formed a white fluffy covering of hyphae on which are produced the conidia. These conidia are hyaline, oblong, and 9 to 12 microns in length. With the further development of the fungus the cavity between the glumes is filled by the mycelial growth which later becomes the sclerotium. Then, in the place of the formerly loose, white conidia-bearing mycelial growth there appears in time the dark blue to black sclerotiad covering. Sometimes two spikelets may be included in one sclerotium. The lower glumes remain usually outside of the sclerotium.

The sclerotia are of various sizes. Under favorable conditions they will grow above the spikelets forming sclerotia free from inclosures. The sclerotia germinate in three to four months. They send out few stipes with sphaeridia, which are yellow in color. The stipes may reach a length

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of eight centimeters and the spheridia a diameter of one to five millimeters. The perithecia have a length of about 300 millimeters and one-fourth or more of each perithecium stands free above the spheridia. The asci are long and cylindrical, 150 to 180 microns long and three microns thick on the apex with a small hyaline cap. The ascospores are thread-like, many septate, and .5 microns in width, swelling in water to three to four microns. Short side branches coming out from the germinating spore soon develop numerous, oval, hyaline conidia, 12µ long and 5µ wide. The hyphae bearing the conidia are markedly thinner than normal vegetative hyphae, which have short, thick cross walls. The conidia are formed in great numbers, and when set free, germinate at once and develop aerial growth and new conidia. According to Möller C. balansioides is a mid-form between Balansia and Claviceps.

Claviceps ? carcina Griffiths and Morris
on Carex nebraskensis, Andrews, Ore.

Mycelium of the fungus extending throughout the entire substance of the parenchymatous tissue of the center of the culm of the host and condenses in one to four places into black, longitudinally striated sclerotia, 1.5 to 5 mm. by 1 to 5 cm., the interior of which is white, of uniform density and made up of loosely interwoven, colorless, thick-walled and sparingly septated hyphae. Faithful but unsuccessful attempts have been made to cultivate the sclerotia of this species, and the placing of the species in the genus Claviceps is, according to Griffiths, a wild guess.

On the whole, the species is very inconspicuous, but when once seen it can be readily detected afterward. The most noticeable effect of the fungus is the rather early death of the culm while the lower leaves are

still green. This, however, is likely to be mistaken at times for the maturing of the plant. Usually the sclerotia are formed in the lower half of the culm and fill its entire vertical section, but they may frequently be formed above the middle and even near the head. The method of liberation of the sclerotia is very interesting. The culm is killed and consequently becomes dry about the time that the sclerotia are mature. In drying, the sclerotia curve into a segment of a circle, thereby rupturing the tissues and falling to the ground. The external resemblance of the sclerotia to those of *Claviceps purpurea* is very marked.

Claviceps cinereum Griffiths on *Hilaria mutica* and *H. cenchroides*, Cachise, Arizona (80)

The sclerotia of this species are clavate, gradually tapering upward, straight, curved, twisted, or contoured, 1.5 - 3 cm. in length by 1.75 to 2.5 mm. in diameter at the base, very viscid while developing, with the base permanently invested by the flowering glumes of the host, which are smooth, shining, black and closely adherent, smooth as far as covered by the glumes, and reticulated for some distance above this. The reticulations gradually disappear upward and merge into closely placed longitudinal striations, which in turn disappear near the apex, where the surface is nearly smooth or irregularly roughened. They are dark grey at the base, but gradually fade out to a very light grey or almost white at the apex. In sections the base possesses an external zone of a dark grey color on the outside, within which is a much wider distinctly marked zone of a very light grey, while the center, less definitely bounded, is almost pure white. At the apex these divisions are absent. Stromata are erect, erumpent with cylindrical or usually slightly fusiform, short, stout, almost white stipe, and a subglobose head, 1.75 to 2.75 mm. in diameter, usually slightly flattened below and overlapping the upper end of the stalk. The head is

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light grey, almost smooth, viscid, punctiform, with small darker points indicating positions of perithecia. Perithecia sunken, not projecting above stromatic mass, ovate to very slightly pyriform, 190 to 225μ by 60 to 90μ. Asci eight spored, fasciculated, narrowly cylindrical, slightly enlarged at attachment, rounded above, and 135 to 150μ by 4 to 5μ. Paraphyses wanting. Spores nearly parallel, filiform, coarsely but rather indistinctly guttulate, 100 to 120μ by 1 to 1.5μ.

Claviceps Junci Adams

The following is Adams' description of this species (1) "The species of this genus are usually found parasitic in the ovary of grasses, sometimes on sedges. Neither in Saccardo's "Sylloge Fungorum" not in Engler and Prantl's "Pflanzenfamilien" is there any mention of the member of the genus occuring on Rushes. The Sphacelia stage only was found, occurring in the ovary of *Juncus glaucus*, and filling up its interior with an immense number of colorless spores. The spores are oblong to elliptical in shape, one-celled, 7.0-10.3μ 2.803.5μ. Obtained on 17th Sept. on Royal Canal bank, Co. Dublin."

Claviceps lutea Möll. on Paspalum (180)

Before the formation of the sclerotia the flowers are covered with a cottony growth of colorless hyphae on which are formed the conidia. The sclerotium is formed here outside on the spikelet in the form of a cap-like curved pod. The largest sclerotia are about three millimeters in diameter. They are attached tightly to the spikelet sending down into its ovorum and between the glumes root-like structures of hyphae. The sclerotia fall down with the spikelets but when they are fully ripe they are easily separated from the spikelets. The sclerotia are white on the inside and distinctly yellow on the outside, having a slight "korneligrauch". Sclerotia germinate after seven months with one or two long, fine, light yellow stipes,

which may reach a length of 4mm. carrying on their tips spheridia. The perithecia are sunken in the spheridia, but their upper parts are elevated in form of spherical bodies (ball). The asci reach a length of 250μ, the ascospores are 180μ long. They germinate immediately in nutritive solution, first they swell up somewhat, divide by cross walls, send out side branches, on which are formed numerous conidia within 24 hours. They are 9 by 2μ. In hanging drops they form aerial growth and numerous conidia.

Claviceps microcephala Tul.

Synonyms:

1. *Kentrosporium microcephalum* Wall (289)
2. *Sphaeria microcephala* ejusd. Wall (279)
3. *Sphaeria acus* Trog. (279)
4. *Cordyceps purpurea* var. Acus Desm. (279)
5. *Sphaeria hookeri* Kl. in Engl. Fl. V. (234)

Sacc. Syl. Fung. v. 2, 565

C. microcephala occurs on:

Phragmites communis	(279)
Molinia coerulea	(279)
Arundine calamagrostis	(279)
Nardus	(277)
Alopecurus pratensis	(193)

Folllowing is Tusasne description of this species (279): "C. tota saturate rufo-violacea, subsolitaria; sclerotio brevi, exili aut crassiore; stipite longo, gracillimo flexuosque; capitulo exiguo molliori."

"Spermogonia eamdem prae se fert fabricam quam supra in Clavicipite purpurea deprehendimus, parique modo in externo pistilli hospitis pariete, quaedam apud Gramina provenit; quoad mollem macrior est

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quam modo descripta, nec 0 mm, 03, longior (submarcida) saepe offenditur. Spermatia fundit ovata s. elliptica, inter se ferme consimilia, 0 mm, 0065 circiter longa dimidioque angustiora; et cum extenuata obsolescit, corpusculum sordidulum deformeque (sacculum Faeo) more solito retert. Stroma s. sclerotium, dum spermogonia informatur, illi se subducit, partimque in ejus sinu reconditum paulatim elongatur, ac formam anguste cylindricam, rectam et utrinque nonnihil attenuatam obtinet. Caeterum ovarri sedem penitus usurpat, sed seminis genini modem excedit, licet glumellis flosculi brevius nonnunquam consistat; millimetra tria aut quatuor in longitudinem plerumque apud Phragmitem tantummodo adipiscitur et diametor 0 mm, 4-5 aequare solet; in Molinia autem majus gereratur . Ex utriculis conflatur globosis, perexigius, oleo scatentibus, parenchymaque firmum, albidum et passum purpurascens sistentibus. Postquam in humenti limo per longam hiemen veluti sepultam jacuit, vere suporveniente, vita in eo evigilatur, nec nisi aestivi temporis ariditate opprimitur. Molis exiguae gratis, paucissimos, sertim, vere proxime elapso, inter gramina sylvulae (*Parisinae*) Boloniensis, in sclerotio (*S. stercorario* DC., ut opinor; dicunt alii *Scl. lacunosum* Pers.) quod insignem *Pezizam tuberosam* Bull. generare solet, facile compertus sum nempe unum aut unum et alterum, rarius tres, fungillos entitur; qui horumce solitarii proveniunt e medio sclerotio quasi ex utero tumente vulgo assurgunt, reliqui prioribus adnascuntur aut matrici externae hinc inde insident. *Clavicipiti purpurea* de universa structura haud dissimiles, stipite pradlongo farcto gracillimo (filiformi) flexuosoque, capituli exiguitate, nec non colore muna potius ferrugineorubente quo ex toto inficiuntur, quam facillime discriminantur. Stipes de longitudine, prout in loco suffocato aut minus obscuro creverit, fariat, centimetrum enim et quod excedit longus aut etiam duplo major offenditur, capitulumque sibi ipsi concolor, vix 0 mm, 7 crassius,

carnosum, molliusculum, et ostiolis obtuse prominulis undique conspersum sustinet. Conceptacula e membrana tenui nec a parenchymate quo obvolvitru facile solubili formata, subovata, obtuse apiculata, 0 mm, 25 circiter longa et dimidio angustiora, thecis linearibus angustissimis erectisque referciuntur, quarum in sinu sporas filiformes nec centimillimetrum longitudine excedentes generari compertum habuimus. Fila haecce octona in asco quolibet proveniunt, septis destituuntur, nec in segmenta postquan dispersa sunt abire videntur.

In floribus *Phragmitis communis* Trin. et *Moliniae caeruleae* Moench., aestivo tempore autumnoque ineunte plantula vigere incipit, nec nisi vere et aestate anni insequentis currentibus perficitur seminaque maturat. Fructiferam legi in paludosis agri Parisiensis (Meudon), domique permultas, alias in Phragmite alios in Molinia natas, prospere colue. Semel occurrit cl. Wallrothio, prope Ebersburgum Germaniae occidentalis, nec non D. Bambergero in Helvetia, teste cl. Trogio; circa Atrebatem, monente cl. Mazorio (in Ann. sc. nat., loc. sup. cit.)., etiam reperta est.

Fungillus modo descriptus a Claviciplte purpurea, dummodo alterum alteri sedulo conferre volueris, nullo negotio distinguitur. Capitulum propter texturam laxiorem, cum modice quidem exsiccatur, subito maxime contrahitur, conceptaculaque in eo immersa quapropter ita prominent et a se invicem discreta veniant ut fructum Rubi exsiccatum quodammodo tunc imitetur. Plantula in aqua aut spiritu vini immersa colorem paulo post liquori cedit.

Fungum non tantummodo in *Phragmite communi* Trin. et *Molinia* caerulea Moench, sed etima in Arundine Calamagrosti L. et aliis graminibus

oriri observationibus a cl. Mazerio relatis declaratum videtur; ego vero fraterque in Phragmite et Molinia supra dictis illius cclerotium hactenus duntaxat offendimus. Mycelium hoc densatum, apud Phragmitem, sub unius e floribus mediis cujuslibet spiculea tegumentis vulgo latet rachi multum adhaeret, et in paniculis quae per totam hiemen ventis quas satae sunt, etiam copiosissiuum vere reperitur. Summum spiculae florem pluries rite fertilem inveni, et ex ejus paleis semen geniunum germansque, non vero prolem gemmiformen exudi."

C. nigricans Tul. on

Scirpus baeothryon	(279)
S. multicaulis	(279)
S. uniflumis	(279)

"C. tota atro-violacea, capitulo dilutiore, nonnihil depresso, mamilloso, papillis (conceptaculis prominentibus) remotis.

De origine, situ et fabrica Spermogonia hujus stirpis cum primogenito antecedentium fructificationis adparatu penitus congruit; Spermatia etiam forma et crassitudine priora subaemulantur. Dum daec disseminantur gliscit sclerotium lineare, semi-cylindricum aut variis modis deformatum, utrigque obtusatum, atrum, intus vero solito more albidum aut squalide purpurascens; quae suppetunt jujus sortis stromata 8-12 millim. longitudine adaequant, sed nonnulla multo breviour constitere. Sicuti Clavicipitibus decet, sclerotium seminiforme ab extrema aestate in verusque anni subsequentis torpescit, nec nisi in limo humido diu jacuerit fructus agere valet. Ideo cum nostris in terris degertibus lux gererosius largitur, sylvarumque arbores sub coelo mitiore facto gemmas explicant ac frondes induunt, tum fungillus noster, dummodo res ei prospere successerint, e hyemali somno evocatur atque ad vitae terminum volens nolens, via praestatuta festinare debet. Ex illius substantis paula-

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tim commutata hinc et inde exeunt, assurgunt, Clavicipites 5-9 aut plures 5-8 millim. altae, totae atro-violaceae sed in capitulo primitus pallidiores. Earumdem stipes crassiusculus filis divaricatis basi destituitur aut pauca exserit. Capitulum quadamtenus depressum 1 ,,, 25 vel 2 millim. diametro metitur et oculo quidem inermi mamilloso-papillosum deprehenditur. Papilae istae conicae, obtusatae, e conceptaculis prominentibus originem ducunt, inter se distant, poroque tandem apertae sporas eructant. Thecae octosporae longissimae, sub apice extremo nonnihil constrictae, tempore debito tenuatae ruptae partimque consumptae evenescere videntur. Sporae liberae factae eo manifestius filiformes, continuae albaeque conspiciuntur.

Oritur hic fungillus in floribus Schiporum, nempe *S. multicaulis* Sm., *S. Boeothryon* Link., *S. uniglumis* link, et consimilium; quos, domi cultos, fructum edentes ad hanc diem vidi in Scirpo uniglumi Link. provenerant, nec audivi ullum mycolegam in parem Clavicipitem (fructiferam) unquam incidisse.

N. B. *Sphaeria Hooleri* Kl. ad Clavicipitum genus verisimiliter spectat, sed ex manca ejus adumbratione, in Smithii *Flora anglica* (t. V, part II (1836), p. 234) edita, aegre perspicitur quae antecedentium habenda sit, dsiquidem quartam speciem sistere non meretur (279).

Clavicep~~t~~s pallida (Wint.) P. Henn.

Synonym:

Balansia pallida Wint.

Following is Winter's description of this species.[1]

"Balansia pallida Winter nova species. Stromata gregaria (ca 4-6), e basi sclerotioidea, in graminum germine parasitica, eumque

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[1] Hedwigia, Band 24, Heft 1, Jan.-Feb. 1887, p.32.

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destruente bulbosa, subglobosa, 1/2-2 Mill. crassa, extus lutea, intus pallida, carnosa orta, sessilia vel stipite plus minusve elongato, saepe curvato flexuosove, interdum subcompresso angulatoque, saepe longitudinaliter sulcato, luteo-albido pradeita. Capitula perithecigera subglobosa, subglobosa, subtus excavata, supra saepe parum tuberculosa et inqequalia, pallidaluteola, ab ostiolis perytheciorum prominulis punctulata, ca 1/3 1/2 Mill. lata. Perithecia in capitulis peritherica, dens stipata, a stromatis substantia vix diversa, elongato obovata, ostiolis papillaeformibus, rotundatis, intensius coloratis stromatis superfieiem perum prominentia, 290-320μ, alta, 130-160μ lata. Asci cylindracei, deorsum attenuati, spice lata rotundati, t unica valde incrassata, 8 spori, 175-220μ longi, 3.5-5μ crassi. Sporae filiformes, ascorum longitudine, tenuissimae, ca. 0.8-0.(μ crassae, hyalinae, septis multis, sed valde indistinctis, - Stylosporae in germinibus junioribus, superfieiem fere totam tuberis sclerotioidei obducentes, e cellulis ejusdem superficiallibus ortae, filiformes, plerumque curvatea flexuosaeque, hyalinae, utrinque acutiusculae, 44-62μ longae, vix 2μ crassae. Brasilia: prope Sao Francisco, Sta. Catherina. In germinibus vivis Luziolae peruvianae Juss. Mai 1885. leg. E. Ule."

P. Hennings (99) makes also the following observation in discussing another species of Claviceps:

"Ebenso ist die Art von Balansia pallida Winter ganz verschieden, welche Art in Fruchtknoten von Luziola Sclerotien bildet. Diese Art is jedoch gleichfalls zu Claviceps als Cl. pallida (Wint.) zu stellen und gehört nicht zu Balansia."

Claviceps pallida (Wint.) P. Henn. var. Orthocladae P. Henn. (101)

Following is P. Hennings' description of this species:

"Mycelie sclerotoideo in germine parasitico eumque plus minusve destruente, subgloboso gyroso compressoque, flavido; stromatibus

gregariis (4-(ca 2-3 mm longis, stipitatis, saepe basi confluentibus; stipite basi bulboso, tereti val late compresso, flavido, villoso, 1-2 mm. longo latoque; capitulis perithecigeris hemisphaericis, subtus excavatis, supra pallide flavis, ab ostiolis prominulis obscurioribus punctulatis 1-2 mm. latis; peritheciis stipatis oblonge oviodeis; ascis cylindraceis, apice rotundato incrassatis, tunicatis, basi attenuatis, 8-sporis 150 - 180 ^{v} μ; sporis filiformibus, hyalinis, pluriguttulatis ca. o.5μ crassis.

Pará , auf Orthoclada spec. auf Fruchtknoten. 19. Dec. 1889.

"Diese Varietät ist von der vorliegenden typischen Form, welche auf Luziola [illegible] t. in Rabenh.-Winter Fungi europ. No. 3549 herausgegeben ist, durch die Grossenverhaltnisse der Stromata wesentlich verschieden, ebenso durch den filzigen Stiel derselben. Vielleicht dürftee diesser Pilz besser als besondere Art aufgerstllt werden, zumal die Unterschiede bedeutender erscheinen als zwischen *C. purpurea* (Fr.) und *C. microcephala* (Müllr.). Die Stromata entwickeln sich aus den Sclerotien and der lebenden Pflanze."

C. paspali Stev. and Hall

Synonyms:

Sclerotium paspali Schw.	(234) Y
Sphacelia pappali borchet	(261)
Spermodia paspali Fr.	(73)

C. paspali occurs on *Paspalum leave* (261) *P. dilatatum* (186) and P. distichum (32) in the United States and Europe. This species was first described by Stevens and Hall, but Brown's description of it (32) which is given here, is more complete.

The sclerotia of *C. paspali* fall to the ground when the grass sheds its spikelets and lie on the ground until spring. Such sclerotia when gathered in winter will germinate about the middle of May and this is usually after the host plants begin to flower.

The sclerotia of *O. paspali* when mature are usually globular in shape, 2 to 4 mm. in diameter, irregularly roughened on the surface, and yellowish gray in color; the interior is homogenous in structure and contains a considerable quantity of oil. Germinating sclerotia produce one to several stromata, usually two or three, with slender whitish stipes 3 to 15 mm. in length and with spheridia about 1 mm in diameter. The spheridia are roughened over the surface, owing to projecting perithecial necks, and are at first whitish in color, later becoming rather bright yellow, and finally brownish.

A vertical section of a stromatic head shows numerous flask-shaped perithecia embedded in the outer part of the head. The neck of each perithecium projects a short distance beyond the surface, thus forming small pimple-like projections. The heads are completely covered with perithecia which are oval in shape and measure by 340 by 119μ. Each perithecium contains numerous slender, cylindrical asci, 150 to 170μ in length. At the outer end of each ascus there is a thimble-like knob fitting over the end. The wall of the ascus is so thin that it cannot be distinguished clearly. The ascospores are filiform and hyaline, being a little less than 1μ in diameter and 70 to 100μ in length. There are probably eight spores in an ascus, although not more than seven were counted with certainty. Mature spheridia from sclerotia just gathered from the field, when allowed to dry slightly and then moistened, exude asci very freely.

Flowers of *Paspalum dilatatum* inoculated with ascospores by by rubbing stromatic heads against stigmas and spikelets of the grass heads

showed abundant evidence of infection in several days. In the field, infected heads are not found for several days after the sclerotia germinate. They are first noticed about the early part of June, about 24 days after germinating sclerotia are first found. Diseased heads become very common during July, especially if June has been rainy.

The infecting fungus attacks the pistil of the grass flower, and in a few days the ovary is almost entirely destroyed, a mass of fungus tissue filling the space it occupied. On the surface of the fungous growth, there are numerous tufts of hyphae standing at right angles to the central mass. Each tuft contains a number of hyphae. The digital ends of these hyphae, or certain of them, enlarge and form conidia. The conidia are hyaline but show granules when stained, oblong, about 5μ wide and 15μ long. They are produced in great abundance and are carried from the hyphae on which they were produced by a droplet of Honey dew.

The sphacelia stage in which honey dew is exuded lasts but a few days. In some cases within a week after the sphacelia stage reaches its height the young sclerotia 1 to 2 millimeters in diameter are projecting from between the glumes of the spikelets. They continue to grow until some reach a diameter of about 4 mm. The sclerotium of *C. paspali* has very marked poisonous properties.

C. Philippii Rehm (209)

Stromata gregaria, e Sclerotio 2-2 1/2 cm. longo, -3 mm. lat., subcylindrico enata, capitata, subglobosa, scabra, stipitata, cum Sclerotio nigerrima. Capitula superficie peritheciis immersis exasperata, 0.3-1.0 mm diam. stipite c.1 mm. alt., 0.2-0.5 mm. lat. intus albida, firma Perithecia immersa, minima, oculo nonarmato vix perspicua. Asci creberrimi, clylinracei, apice rotundati et incrassati, 120-150μ lg., 6μ lat. 8 spori. Sporidia filiformia, recta, 1 cellularia, subflavidula, parallele posita,

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c. 120μ long, 1μ lat. Paraphyses desunt.

Mergni (Chili) leg. Th. Philippi. Ad sclerotium intra vaginam folii sessile, caryopsidem infectans."

C, pusilla Ces. (37)

"Clavicipili microcephalae et purpurea affinis. differt colore stipitis stramineo et capituli fuscostramineo, dintissime persistente, praecipue vero appendice collariiformi capituli basim ambiente, basigue stipitis glaberrima; ascis sylindraceis 56 x 6μ; sporidiis filiformibus ascum aequantibus.

Hab. in caryopside (affecta a Sclerotii Clavi forma) Andropogonis pr. Brescia et Vercilli in Italia boreali. Perithecia globulosa 1/5 - 1/4 mill. diam., in ostiolum conicum producta. cr. Aapitulum 1/2-1 mill. diam."

C. ranunculoides Möll. on Setaria sp. (180)

This species has typical Claviceps sclerotium, horny and curved. In the sphacelia stage the fungus seems to be of an orgnge-red color. The numerous conidia formed here are oval, 7 to 8 by 3 to 4μ. The sclerotia germinate first after nine months. The stromata are slightly yellow at the base, as in C. purpurea, somewhat thickened, and covered with hyphae. The spheridia have the form of Ranunculus on which only the upper middle perithecia are developed symmetrically, the others being curved and bent in all directions. The perithecia, though they are free and superficial, yet are partly sunken into the spheridium, which extends half way up to the semispherical apex of the perithecia. The perithecia are from the base to the apex from 400 to 500μ long. The thread-like asci have very flat apices and reach up to 300μ in length and 4μ in width. The ascospores are filamentous, 100μ long with about 30 cross septa. On the day after transfer the ascospores break into segments which germinate

separately, the germ tubes coming from the ends of the segments. Four days later there is formed a rich aerial growth of conidia bearing hyphae.

C. Rolfsii Stev. and Hall (261) on Paspalum leave and *P. dilatatum*. Syn. Sclerotium paspali Schw.

Sphacelia paspali Bornet

Spermadia paspali Fr.

As *C. Rolfsii* and *C. paspali* differ only in their ascigerous which was only recently found, it is necessary to give here also the synonyms given for *C. paspali*, as their similar sclerotia have been referred to indiscriminately under the same synonyms.

Sclerotia yellow to gray, globose, roughened when mature, about 3 mm. in diameter; spheridium dull yellow; stipe filiform but thicker than in *C. paspali*, 1 to 1.5 cm. long; peritheric few in spheridium and mostly upon extreme distal portion; cylindrical, ovate, 816 by 225µ; asci cylindrical, 375 by 3µ; spores filiform, 260 to 275 by 0.5 to 1µ.

C. sesleriae Stäger on *Sesleria coerulea* and possibly on *S. argentea*. (225)

The Claviceps of Sesleria has been listed as *C. purpurea*, but Stäger, who made a careful study of the fungus and made a number of inoculation experiments with it, considers it as a distinct species which he called *C. sesleriae*. It does not pass to any of the typical *C. purpurea* hosts and is morphologically somewhat different from the latter. The conidia of *C. purpurea* are 7 by 3.5µ, the conidia of *C. microcephala* are 7 to 8 by 3 to 5µ, whereas those of *C. sesleriae* are 10.5 to 14, by 3.5 to 5.3 to 7µ. Besides a cross section of the sclerotium of *C. sesleriae* represents a different picture. In the middle of the white mass of the sclerotium there is a darker portion in a star-like form.

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Here is Stäger's diagnosis of C. sesleriae. "Stromasive sclerotium fungilli vulgo linearo-oblongum , obsolete trigonum, restum arenatumve, e parenchymate densissimo duro albido constat, cujus media pars in stellae figuram redacta obscura.- Capitula crassa, primum pallida luteolaque, postea purpureoviolacea.

Spermatia ovato-elliptica, O. mm, 0105 usque ad 0 mm, 014 circiter longa, 0 mm, 0035 usque ad 0 mm, 007 lata nonihil in medio constricta praetereaque nuceolis duobus oppositis donata."

C. setulosa (Quél)Sacc. on Poa (26)

Syn. Cordyceps setulosa Quél.(202)

Spheridium 1 mm in diameter, globose, leathery brown colored, slightly warty, because of the fine papillae; stipe flexuosus slender, 1 cm. long, erect, covered at the base with white silk-like hyphae, ascospores straight, filiform, 50µ in length.

Ergot on Poa in the pastures of Jura mountains, France, C tripsaci Stev. and Hall on Tripsacum dactyloides (261).

In late summer and well into winter characteristic fungous growths are often seen protruding from the basal, ovulate, portions of the spike. Sometimes nearly every spikelet is affected. The structures are white from 12 to 20 mm. long, and about 2 to 3 mm thick. Toward their tips they may be browned and more shrunken than in regions near their bases. Examination of the affected spikelets show the seed to be absent and their place to be occupied by white sclerotia approximately the shape of the seed of the host. In general, the appearance is that of a Claviceps sclerotium except that it is white and soft, the protruding horn being the remnant of the summer stage.

Throughout the early part of the season the protruding part bears myriads of straight to lunulate spores, showing strong resemblance to the ordinary lunulate Fusarium spore.

In spring the sclerotia germinate, the stipes forking and producing two or even four heads upon the same stalk. Following is Steven's and Hall's diagnosis of the fungus:

"The sclerotia of *C. tripsaci* is smooth, white to dark brown or black, nearly conical, 4 to 5 mm. in diameter at base; spheridia, gray to grayish-white, stipes thick, white to purplish white, 1 to 1.5 cm. long; perithecia numerous, elliptical in longitudinal section, with a short beak toward the surface of the spheridium, 390 by 155 to 187μ; asci cylindrical, 145 to 175 by 2 to 3μ; spores filiform, 130μ long; conidia hyaline, continuous, fusoid to lunulate, 17.4 to 37.7 by 2.9 to 8.7μ."

C. wilsoni Cooke (44) on *Glyceria fluitans*

Synonyms: *Barya aurantiaca* P and Wils. *Claviceps purpurea* Tul. var. Wilsoni W. Smith.

Plowright and Wilson (195) described first this species as a parasite on ergot under the name *Barya aurantica*, as they could not get infection with the spores on wheat, on rye, and on *Poa trivialis*. They should have tried *G. fluitans*. At that time it was considered as an abnormality of *C. purpurea* and W. Smith described it under the name *C. purpurea* Tul. variety Wilsoni. He thought that this variety owed its origin to its peculiar environment, so different as it is from the environment of wheat, rye and other cereals, namely, wet and muddy places in stagnant pools and slow-running streams.

The sclerotium of *C. wilsoni* differs from *C. purpurea* in being whitish or yellowish instead of pale purple in color, and in the perithecia being almost free on an elongated club-like growth instead of being immersed in a globular head. Many of the stipes of this species are hair-like, others are attenuated upwards from a thicker base and the sphaeridia bear no perithecia. The whole growth is less firm than that of *C. purpurea*. In some instances the base of the stipe is so thick that the Claviceps superficially

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resembles a parasite upon ergot rather than a true fruiting condition of ergot itself. Sometimes this effused mycelium spreads over the ergot, and several clubs arise from one stratum of mycelium, which may have emerged from one minute hole or crack in the sclerotium. The poles of the grass flower are sometimes attached to the sclerotium.

The perithecia are superficial, scattered throughout the upper half or two-thirds of the club-shaped stipe, on the average the same in size and character as those of C. purpurea. In cross section they do not differ from C. purpurea. The asci are cylindrical, 200 to 250 by 30μ. The conidia are elliptico-lanceolate, borne in chains on the end of branching conidiophorous hyphae, and 10 to 12 by 2 to 3μ.

C. wilsoni has been reported from Great Britian and Switzerland. It is probable, however, that it occurs in other countries as well but has been overlooked.

Claviceps sp. on Spartina stricta

Thaxter (248) who first found this fungus, thinks that it is a species as different from C. purpurea as is C. microcephala. He concludes this from the fact that its sclerotia germinate first toward the end of June and the beginning of July. No other information concerning this species is available.

Claviceps sp. on Zizania awuatica and Z. palustris

This species of Claviceps which has not been studies in detail has been referred to by several men under the name C. purpurea Tul. Fyles (76) who studied it and conductod some inoculation experiments, finds that its sclerotia germinate two months after gathering and usually send out numerous stromata. The greatest number he observed was forty-eight and the least eleven. Broken pieces of ergots produced 3 to 7 stromata. The spheridia of the stromata are light buff in color with lavendar stalks, be-

coming deeper brown and slightly reddish with age, and 2.5 to3.5 cm in diameter. The ostiloles give it an apparance like diminutive spiked clubs and the stipes reach a length of about 5 cm. At the height of maturity, the perithecia measure 250 to 325µ in length and 150 to 160 in width. The asci are 200 to 215µ long and 4µ wide. The spores are 150 to 180µ long, triceptated. The conidia measure 9 to 12µ in length and 2.5 to 3.5µ in width. Because of the difference in the measurement of conidia the ascospores of this Claviceps and C. purpurea and the fact that plants readily infected with spores of the latter proved immune in his experiments and from some other biological features, Pyles feels justified in considering this ergot a distinct species, the diagnosis and scientific name of which he will give in his forthcoming paper upon the completion of his work.

INFECTION EXPERIMENTS AND SPECIALIZED RACES OF SOME CLAVICEPS SPECIES

As is the case with other cereal diseases, it has been suspected for a long time that the Claviceps of cereals and grasses is not one and the same species on all of the numerous plants attacked by it. Stager is the first and only worker who has studied some of the known Claviceps species from the standpoint of specialized races. He did this work during a period of over ten years and contributed much toward the better understanding of t this genus. Valuable as his work is, much more is needed and further studies will, no doubt clear up many points which are not well understood.

The results Stager obtained are convincing as far as they go, but a greater number of inoculations, especially cross inoculations, may give somewhat different results, or at least eliminate the last doubt as to the correctness of this work.

The methods used by Stager in his inoculation work with Claviceps are very simple. The plants to be infected are brought to the greenhouse, or any other room, a week before flowering so as to avoid external infection. The infected plants are kept uncovered in the greenhouse, or under jars,

according to the kind or kinds of inoculum used. Stäger in most cases used conidia for inoculation. In such cases the "honey dew" is gathered carefully in small bottles from the infected plants, corked tightly and kept in the dark until used. Before inoculation the "honey dew" is diluted with water and the heads to be infected are either dipped in the dilution or sprayed with an atomizer. Ascospores may be used in the same way.

The plants are inlculated always at the time of flowering, never before or after flowering.

This species goes to:

Alopecurus pratensis ?
Anthaxanthum odoratum
Arrhenatherum elatius
Briza media
Bromus sterilis
Calamagrostis arundinacea
Dactylis glomerata
Festuca pratensis
Hierochloa borealis
Hordeum murinum
Hordeum vulgare
Phalaris arundinacea
Poa alpina [1]
Poa caesia
Poa concinna [1]
Poa hybrida
Poa pratensis
Poa sudetica

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1. Only very slight infection, results not convincing.

It does not go to:

Bromus erectus

Molinia coerulea

Poa annua

Poa fertilis

Triticum spelta[1]

The C. purpurea from rye attacking the above listed plants is considered by Stäger as the typical C. purpurea in distinction from other C. purpurea which shall be considered in the following pages.

Inoculation experiments with C. purpurea from Festuca arundinacea (273)

Claviceps from Festuca goes to:

Anthoxanthum odoratum

Arrhenatherum elatius

Dactylis glomerata

Melica nutans

It does not go to:

Bromus erectus

Poa alpina

Anthoxanthum odoratum is easily infected in this case but no sclerotia or only rudimentary sclerotia are formed.

The Claviceps of Festuca arundinacea is typical C. purpurea of rye as it goes easily to some of the common hosts of the latter species.

It is interesting to note here that Melica nutans is host of two different species of Claviceps, the first being C. sesleriae. In both cases, however, it can be infected only under artificial conditions.

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[1] The cause may be the closed flowers or else its ergot is a different specialized race.

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Infection experiments with Cl. purpurea conidia from Anthoxanthum odoratum, infected originally with ascospores of C. purpurea from rye. (248)

Bromus sterilis

Calamagrostis arundinacea

Festuca pratensis

Hordeum murinum

Hordeum vulgare

Poa compressa

Poa sudetica

It does not go to:

Bromus erectus

Glyceria fliutans

Glyceria distans

Lolium italicum

Lolium perenne

Lolium temulentum

Nardus stricta

Poa alpina

Poa annua

Anthoxanthum odoratum is easily infected with C. purpurea of rye, and the conidia produced on it in turn infect the typical hosts of this species. Sclerotia are, however, never or very seldom formed on Anthoxanthum odoratum by the typical C. purpurea of rye. A special biologic race of the same, which we shall consider next, produces abundant sclerotia on the host.

Claviceps purpurea. Sclerotia forming biologic race on Anthoxanthum odoratum (252)

This race goes to:

Anthoxanthum odoratum

Arrhenatherum elatius

Holcus molle

Poa pratensis

Secale cereale

It does not go to:

Hordeum vulgare (single plant in the field)

Dactylis glomerata [1]

Koeleria valesiaca

Lolium perenne

Milium effusum [1]

Sesleria coerulea

Morphologically the sclerotia forming Claviceps of A. odoratum is the same as C. purpurea, the only difference being that this forms abundant sclerotia on A. odoratum while the typical C. purpurea from rye which also attacks A. odoratum never, or only very seldom, forms sclerotia on this host, and the sclerotia when formed are very abnormal and small.

Claviceps purpurea biologic form from Brachypodium silvaticum (248 and 251)

It goes to:

Brachypodium silvaticum

Milium effusum

Poa pratensis

Poa trivialis

It does not go to:

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[1] In poor condition at time of infection; result uncertain.

caespitosa
Aira ~~caespitosa~~

Anthoxanthum

Arrhenatherum elatius

Holcus mollis

Lolium italicum

Molinia coerulea

Poa alpina

Secale cereale

Sesleria coerulea

Conidia from Milium effusum infected with ascospores from ~~Brachypodium~~ ~~Brachypodium~~ Brachypodium silvaticum do not go to:

Aira caespitosa

Arrhenatherum elatius

Brachypodium
~~Brachypodium~~ pinnatum

" " var. caespitosum

" silvaticum

Bromus erectus

Glyceria fliutans

Poa cereale

" nemoralis

" pratensis

" trivialis

In connection with this experiment is the interesting fact that Poa trivialis and P. pratensis are slightly infected by ascospores from B. Silvaticum only a very small amount of honey dew being secreted and no sclerotia formed. On the other hand they are not at all infected by conidia from the same, as is shown in the case of inoculations with conidia. from Milium effusum. It is to be noticed from previous experi-

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ments that the poa species are infected only temporarily by various biologic races of Claviceps.

It is further interesting to note that *Brachypodium silvaticum*, the only real host of this form, flowers much later than the fungal ascospores are produced, and that direct infection is impossible. The fungus has been forced, therefore, to adapt itself to another host which is found usually in association with the first and which flowers just about the time of ascospore production. This is *Milium effusum.* *Milium effusum* is in blossom about the end of May and at the same time the ascospores are discharged from the perithecia. These spores germinate, establish themselves very easily on *M.effusum* and produce an abundant and long-period secretion of honey dew. Sclerotia are not formed, however on *Milium effusum*, or only very seldom, and such, when occurring, are only rudimentary.

Meanwhile, the *B. silvaticum* sends out its flowers which can easily be infected with the conidia produced on *M. effusum*. Then numerous sclerotia are formed. There are necessary, therefore, for the full development of the fungus, under normal conditions, two host plants; *Brachypodium* silvaticum and *Milium effusum*. For this phenomenon we find an analogy in *Sclerotinia ledi*.

As is known, Woronin described for the first time (1896) an Ascomycetous form with heteroeceous habit (*Sclerotinia ledi.*) At the time of ascospore ripening of this fungus the host Ledum is not yet developed. The spores infect first Vaccinium uliginosum which is in proper stage of development at that time and from the latter the fungus paeses to its true host.

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Claviceps of milium effusum. Same as on B. silvaticum (248)

It goes to:

Brachypodium silvaticum

Milium effusum

It does not go to:

Arrhenatherum elatius

Festuca pratensis

Holcus mollis

Secale cereale

This shows that the Claviceps on Milium effusum is the same as that on Brachypodium silvaticum and that it is not the same as the C. purpurea from rye hosts.

Infection experiments with Claviceps of Lolium perenne (248)

Claviceps from L. perenne goes to:

Bromus erectus

Lolium italicum

" perenne

" temuleutum

It does not go to:

Aegilops bicornis

Alopecurus pratensis

Anthoxanthum odoratum

Arrhenatherum elatius

Brachypodium silvaticum

Bromus macrostachys

Panicum sanguinale

Poa pratensis

Secale cereale

Morphologically this species does not differ from C. purpurea on rye and is, therefore, a biologic race of the latter

Inoculation experiments

Claviceps microcephala Tul. from Phragmites communis (248)

It goes to:

Molinia coerulea

Nardis stricta

It does not go to

Alopecurus pratensis

Anthoxanthum odoratum

Arrhenatherum elatius

Hordeum murinum

Lolium perenne

Poa hybrida

Poa nemoralis

Poa sudetica

Poa trivialis

Poa"Sponischer Doppelroggen"

Conidia from the same species and biologic form from Molinia coerulea upon infection gave positive results on:

Aira caespitosa

Molinia coerulea

Nardus stricta

It does not go to:

Calamagrostis arundinacea

Poa species

Sesleria coerulea

Conidia from Aira caespitosa produce infection on Molinia coerulea, but do not infect Spanish double-rye.

It infects: Poa amma

It does not infect:

Aira caespitosa
Arrhenatherum elatius
Bromus erectus
Hordeum sativum
Lolium italicum
" perenne
" rigidum
Panicum miliaceum
Poa alpina
Poa caesia
Poa cenisia

These results indicate that the Claviceps of Poa annua has only one host and that it does not pass to the typical host of C. purpurea on rye. Its host is not infected by any of the other Claviceps sp. or by C. purpurea biologic races as shown in previous experiments.

In his paper (250) Stäger considered this fungus as a distinct biologic race of C. purpurea of rye, but in his later paper, (252), after careful morphological study of its ascigerous stage, not made before he considered it as a biologic race of C. microcephala, of Phagmites communis, and called it Claviceps microcephala Tulasne, spez. biologica Poae.

Infection experiments with Claviceps of Sesleria coerulea from Twann Switzerland (248)

It goes to:

Melica nutans

" uniflora

Sesleria coerulea

It does not go to

Anthoxanthum odoratum

Arrhenatherum elatius

Brachypodium caespitosum

Bromus erectus

Dactylis glomerata

Festuca pseudomyurus

Holcus molle

" lanatum

Hordeum bulbosum

Koeleria valesiaca

Lolium perenne

Milica ciliata

" effusum

Poa pratensis

Poa alpina

Secale cereale

In nature Claviceps sclerotia or the conidial stage of same are never found on Melica uniflora and M. nutans. Infection takes place only under artificial conditions and here it is only slight, sclerotia being never formed.

Claviceps from the same host and from Leuenen infects only Sesleria coerulea, but does not go to any of the above listed hosts of this Claviceps. This shows that the climate and locality might have some effect upon the adaptability of Claviceps to some hosts. Stäger considers

Claviceps from the same host and from Lauenen infects only Sesleria coerulea, but does not go to any of the above listed hosts of this Claviceps. This shows that the climate and locality might have some effect upon the adaptability of Claviceps to some hosts. Stäger considers the Claviceps on Sesleria coerulea not only as a biologic race of the C. purpurea on rye, but he thinks that it is a distinct species to which he gave the name C. sesleriae, under which name it is described in another place in this paper.

Infection experiments with Claviceps from Glyceria fliutans (248)

It goes only to Glyceria fliutans, but does not go to:

Aira flexuosa

Ammophila arenaria

Anthoxanthum odoratum

Arrhenatherum elatius

Brachypodium sylvaticum

Bromus erectus

Calamagrostis arundinacea

Cynosurus cristatus

Dactylis glomerata

Festuca pratensis

Holcus mollis

Lolium perenne

Nardus stricta

Poa annua

Poa pratensis

Poa sudetica

Secale cereale

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Stäger did not make detailed morphological study of this species but he thinks that it is the same as Claviceps Wilsoni Cooke.

Inoculation experiment with Claviceps from Zizania (76)

This species goes to:

Zizania aquata

Zizania palustris

It does not go to:

Agropyron tenerum

Alopecurus pratensis

Arrhenatherum elatius

Avena sativa

Dactylis glomerata

Elymus dsystachys

Hordeum vulgare

Poa pratensis

Secale cereale

Fyles (76) considers this fungus as a distinct species, different from C. purpurea and from all other known species.

TOXICOLGY

History

As early as Caesar's and Galen's (1) times some diseases among man and beast have been attributed to impurities in the grains. The epidemics reported during the middle ages and known as "Ignis sacer" were at least partly due to ergot. While such epidemics have been rare during the last two or three centuries, they were much more common during the early times. The"Holy Fire" in 922 in Spain and France alone is supposed to have taken 40,000 lives.

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Some of the most important known epidemics presumably caused by ergot are those in Silesia in 1588, Saxony in 1648, Cologne in 1690, Freiburg in 1702, Switzerland in 1709, Silicia in 1736 where 300 out of 500 cases resulted in death. In this case, the king of Prussia ordered an exchange of sound rye for the affected grain. There was similar trouble in Denmark, Sweeden and Norway, 1761; Westphalia in 1770, and 1771; Lorraine and Burgundy in 1816; Nassau in 1856. In later years epidemics have been more frequent in Russia. In 1854 an epidemic broke out in Crimea among the soldiers, in 1862 in Finland and in various other provinces in 1865, 1872, 1879, and 1880. In 1884, there were many cases of ergotism in the province of Poltava, where many people died, lost a hand or foot due to gangrene, or became paralyzed for the rest of their lives. Since that time several severe epidemics have occurred in Russia. Single cases have been reported during the ninteenth century in Berlin, Pommern, Braunschweig, Great Britian, various districts in France, United States and Bulgaria. In 1608, after inundations and heavy fogs there was a general epizootic among the cattle in Germany. In recent years a number of ergotism cases among cattle and horses have been reported from various countries.

Ergotism as known now is a disease of bovines caused by the consumption of considerable quantities of food contaminated by ergot. Equines are apparently less susceptible than bovines, although the horses have been known to suffer sererely from this disease. Ergotism in men is not an unknown occurrence at present, and in nearly every instance it has resulted from eating bread made of ergotized grain.

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(1) Galen, Claudius. Greek physician and medical writer. A. D. 130 - 200 ?

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Ergot also causes abortion and in some years the loss to stockman from abortion of cows and mares is heavy. This is greater in seasons when there is an unusual abundance of ergot on the grasses. It is certain also that the general health of the animals is impaired by ergot.

The properties of ergot to inhibit proper blood circulation and to cause abortion have been known ever since the middle ages. Lonicer selected and used ergot as a drug in 1573 and ever since it has been regularly used as a drug in cases of protracted labor and excessive haemorrhage. It is claimed, however, by Bauer (15) that Dr. Stearus, of New York England, was probably the first who used ergot most effectively in such cases about 1822.

Ergot composition

The exact chemical composition of ergot is not well understood. A number of compounds have been isolated by various workers but just what they are, their chemical formulae, and properties are not well known in all cases.

In 1875 Tanret (266) succeeded in isolating a pure substance from ergot which he called "ergotinin".

In 1884 Kobert (136) discovered three new bodies in ergot: ergotinic acid, cornutin, and sphacelic acid. These, according to the author, are not chemically pure bodies but only physiologic actions. Ergotinic acid is a nitrogenous glucocide without action on the uterus and narcotic in its effects. It is a protoplasmic poison, and when injected intravenously produces inflammation of serous and mucous membranes, disintegration of red-blood cells and widespread ecchymoses. In sphacelic acid Kobert thought he had discovered the agent causing contraction of the uterus, while he considered cornutin as the agent causing strong convulsions and later paralysis and not the pain causing constituent of ergot. In his later work (137) he attributed the medical action of ergot to cornutin.

This shows that he was working in the first case with chemically impure substances.

Keller, 1896, (131) worked out a method for the quantitative determination of the alkaloids in ergot and found that the only pure alkaloid present in ergot was identical with the "Ergotinin Tanret", which was declared earlier by Kobert as inactive. Further Keller, as well as Tanret, claimed that Kobert's cornutin was partly decomposed ergotinin. In spite of this disputed question, Keller preserved the name cornutin for the pure alkaloid and considered it as the bearer of the ergot properties.

Santesson (228) gave a pharmacological test to Keller's original preparation and came to the conclusion that cornutin did not have the properties of causing contraction of the uterus and that it has only a rather weak poisoning property.

Jakoby (122) basing his conclusiong primarily upon pharmacological experiments, found that not an alkaloid but a notrogen-free substance of phemol-like nature was the active agent. This active agent, which he called sphacelotoxin, is of a more hypothetical nature. Sphacelotoxin acts on bases as well as on acids. Such a compound with an acid is the chrysotoxin and the same with an alkaloid is the secalintoxin. By purification the secalintoxin loses its action. In pure condition it is called secalin, which is nothing else but ergotinin.

Such was our knowledge of the composition of ergot at the time (1901) when Kraft took up the study of this question. He worked for five years on this problem and was able to give a somewhat more complete list of the compounds found in ergot.

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According to Kraft, ergot contains: ergotinin (Tanret); two alkaloids, crystalized ergotinin (Tanret) and amorphous hydroergotinin (Kraft); a group of yellow colored lactone acids: secalone acid and its amorphous relatives; a white independent acid; and also the otherwise common substances: batin, cholin, and mannit.

The alkaloids are convulsion and gangrene producing poisons, but not the agents of the specific action on the uterus.

At the same time, Professor Vahlen (282) published his work on clavine, a new crystalized substance which possesses the specific action of causing contraction on the uterus. This completes the list of known chemical compounds found in regot.

Vahlen isolated a pure substance from ergot called Clavine which stimulates the contraction of the genital organs but lacks entirely the gangrenous and other properties of ergot. The quantity of clavine amounts to several grams per Kilogram of ergot. It has a dull taste and is not colored by the alkaloid reagents. On the uturus it has a specific action which it stimulates to more or less rapid contraction. Up to the present there have been successfully applied doses of 0.02 grams in subcutaneous injections or in tablets.

Barger and Dale (12) claim that the amorphous alkaloid which Kraft called and considered as hydroergotine is not exactly hydrolized ergotinin and that it should be called ergotoxin as Barger and Carr (11) had named it only a month before Kraft's paper was published. Contrary to Kraft's and Vahlen's assertion they showed by numerous experiments on various animals that the action of ergot was due to two substances.

The alkaloid ergotoxin $C_{35}H_{41}O_6N_5$ they claim is chemically and physiologically identical with Kraft's hydroergotinin, causing

gangrene on the combs of hens, increasing of the blood pressure and contraction of the uterus. These actions are caused by the alkaloids and not as Vahlen supposed by an impurity found in it. This alkaloid is the specifically active part of preparations like sphacelic acid, sphacelotoxin, etc. In water extracts of this alkaloid it comes only in small quantities.

In water extracts which cause also an increase in the blood pressure and contraction of the uterus, the active principle is the watersoluble base, p-oxyphenyl-ethylamin, $HO.C_6H_4.CH_2.CH_2.NH_2$, which resembles aerenalin chemically as well as physiologically.

They showed also that the clavine preparations are a mixture of amino acids and not a pure substance as Vahlen held it to be.

The quantitative composition of ergot is even less known than its qualitative composition. It probably varies with samples, small ergot is supposed to contain more alkaloids than the larger ones. According to Hartwich, (90+, Cl. microcephala contains three times as much ergotinin as those of Cl. purpurea.

Ergot is supposed to contain (205) about 30 percent fixed oil ( ). Besides this the Spanish ergot contains about 0.3 percent ergotinin, Russian and German about 0.2 percent, Others have given smaller percentages of these compounds.

Some other substances have been reported as being also present in ergot. Such are: a sugar called mycose, 30 percent a yellowish oil consisting of fats, (30 percent) principally olein and palmetin, glycogen (95), callose (168). The latter is probably identical with fungose, mycosine, etc.

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Tests for ergot

Because of the toxic properties of ergot it is absolutely necessary to have some way of determining the presence of ergot in flour and bread, as well as in the milling products fed to animals. There are at present several ways in which this can be done, and there are some differences of opinion as to which is the most accurate and practicable.

Ergot can be determined in such products by treating a small amount with an alkali or an acid (177). With the first it gives a violet, with the second a red color. Absence of color shows that no ergot is present in the treated sample. A good method is to take two grams of flour, add to this 10 cc. acid alcohol (a solution containing 70 percent alcohol and 15 percent concentrated hydrochloric acid). It will give a red color even when only 0.2 percent ergot is present(71). Some claim that this method is unreliable because there are other impurities in flour which may also give red color while others insist that no other impurities give this reaction. By heating a portion of the sample with a solution of caustic potash a characteristic herring or trimethylamine odor shows the presence of ergot.

The following is a microscopical test for ergot in flour. One milogram of flour is placed in a drop of water on a slide, this is then heated to the boiling point. The starch streams away immediately, permitting an undisturbed observation of the object. The ergot particles are very characteristic and by a magnification of 100 to 120 can be distinguished from other tissues by their density, by their dark violet color at the edges, the greenish yellow color of their cross walls, and by the particularly indented edges. According to Max Gruber (83) this method is exact, expedient, easy to use and applicable for bread and baked foods. Others have criticized the method severely and doubted its usefulness.

In the colorimetric method a sample of flour or bread is first boiled in absolute alcohol, the alcohol is changed, and the boiling continued until no more yellow color is given off. Then to it is added some Vogel's alcohol and boiled again, the ergot color dissolves rapidly in this alcohol and the whole mass soon begins to become red in color. When to 20 grams of flour is added even 0.1 gram of ergot, the red color is still plaihly visible. The solution is then carefully filtered until perfectly clear and compared in the colorymeter with a standard solution of ergot. Herrmann (102), who first used this method, found that not all of the ergot present can be determined but only three-fourths of it. For this reason he thinks that all methods for determination of ergot based upon this principle are not good for quantitative determination of ergot. He found, however, that flour containing even 0.5 percent of ergot will show a distinct red color when tested by this method, and this is close enough to make the method useful for practical purposes.

E. Hoffmann's method modified somewhat by Lauck (148) is according to the latter, a much better method for ergot determination than any of those previously described. In this case, to 10 grams of a well mixed sample are added 20cc. (of coarser brans etc. 30 cc.) of ether distilled first over natrium. To the above is then added 1.2 cc. of 5 percent of H_2SO_4, the whole is thoroughly stirred and allowed to stand for six hours in well closed glass bulbs. The whole substance is then poured into a double filter moistened with ether and then washed with ether until the filtrate is brought up to 40 cc. The filtrate is placed in a test tube with a round base and to it is now added 1.8 cc of saturated solution of "doppelkohlensaurennatrium". After a thorough stirring, part of the liquid separates on the bottom of the test tube which varies in color, according to the amount of ergot present, from very light to dark violet.

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Samples with very small amounts of ergot do not show any color when tested by this method. Lauck was able, however, to show the presence of at least 0.5 per cent of ergot. He established also that ergot loses with time some of tis coloring matter and that no other impurities in flour of plant origin give the same color or any color at all.

Mjöen (178) has given us the spectorscopical way of ergot determination, but this is so complicated and of so little practical value that it will not be worth while to describe it here.

Strasburger (263) has given us a test for ergot in the faeses. The faeses are mixed with water, sedimented and the sediments obtained further purified and then tested for ergot by the addition of acid which gives a characteristic red brown color to the ergot tissue with its enclosed oil drops. This color is visible upon microscopic examination. Ergot, as is also true of other fungi, because of its chitinous, membranous nature is very slowly digested so that after taking it even in small doses the ergot will come out with the faeses unchanged.

Ergotism

Ergot has very marked toxic properties and when taken in by animals in considerable quantities with infected hay, grain, or in the pasture is apt to bring about distinct pathological conditions, depending upon the kind of ergot, amount consumed, and length of time during which ergot has been fed in one or another form, and also upon climatic conditions. Cattle, horses, mules, sheep, hogs, dogs, cats, and fowls are known to suffer from ergotism.

Kobert (136), who experimented chiefly with cattle and fowls, found that an acute case of the poisoning can be distinguished from a chronic case also a gargrenous ergotism from a spasmodic. The disease manifests itself among animals chiefly in the chronic form, since

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as a rule, the poison is acquired in small amounts, and accumulation taking place slowly.

The gastroenteric symptoms of the disease are; an excessive salivation accompanied with redness, blistering inflammation, wasting and gangrenization of the mouth-epithelium. Similar changes also occur on the epithelium of the gut, producing vomiting, colic, diarrhaea, and constipation. These symptoms appear in both spasmodic and gangrenous forms of ergotism. In the spasmodic type of the disease, symptoms of over-stimulation of the central nervous system appear. There appears also tonic contractions of the flexor tendons of the limbs, anasthesia of the extremities muscular trembling, general tetanic spasm, convulsions and delirium. Nervous phenomena, such as insensibility, blindness, and paralysis also appear.

Gangrenous ergotism is attributed to prolonged constriction of the arteries and more directly perhaps to degenerative changes in the vessel walls, and the consequent formation of hyaline thrombi. It is characterized by coldness and anaesthesia of the extremities, followed ultimately by dry gangrene of this part. The effects of this dry gangrene are often very serious and amount to sloughing off of the feet, tips of the ears, tip of the tail, shedding of the hair, teeth, etc. The most frequent lesions are those of loosening of the hoofs so that parts of the sole or wall may shed or slough off. This trouble is found more in cold weather than in warm weather, although this is not always the case. The extremities, such as the ears, tail and lower part of the limbs, gradually begin to lose their warmth and sensibility, dry gangrene sets in, the parts harden, become mummified, and finally drop off without pain. Death takes place from exhaustion. With the exception of the gangrene, which may vary slightly in severity, there are no lesions of special significance. Degenerative

changes in the sensory area of the cord, in the vessel walls have been observed in animals slowly poisoned with ergot.

The disease makes its appearance among cattle chiefly in winter and spring seasons and has, at times, been the cause of serious losses throughout the central and western states.

Consumption of ergotized hay by pregnant animals, especially cows, may cause abortion. Grass containing ergot is especially damaging to animals at the time when the uterus is nearly ready to exclude its contents. The ergot varies in its character and strength according to the variation of the season and local conditions under which it has been grown, as well as the time or stage at which it is harvested, so that the ergot of one year appears to be comparatively harmless, while that of another year, or season, or locality is very injurious. The fact remains, however, that under given conditions of growth it unquestionably causes ergotism and abortion, and in such cases the abortions are widespread in the herd or in different herds in the same district. Cases such as these are easily mistaken for contagious abortion though there is in the system of the aborting animal no self-propagating germ which will produce the disease if transferred to another animal.

The toxicological effects of ergot have been tested experimentally on dogs, cattle, swine, poultry, guinea pigs by Tessier, Brown, Ranck, and others. The results obtained are the same as described above.

Horses are also subject to ergotism. Wilcox (295) reports a case where several horses upon eating hay which contained a great number of ergot sclerotia dies within six to twelve hours. The horses showed the following symptoms: a general depression of the vital functions, the respiration and pulse being slow and the sense organs being less responsive

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than usual. The course of the disease was usually a rapid one and ended in the majority of cases in death within from six to twelve hours, the symptoms during the latter stages of the disease being those of a general and aggressive paralysis of the whole muscular system and muscular incoordination. The animal would lie down and get up rather frequently but did not show any excitement or pain, and death resulted in a very gradual manner. A post mortem examination disclosed that the stomach contained considerable quantities of blue joint which was badly infected with ergot. Numerous ergot sclerotia were still undigested.

Horses pastured on land with infected Agropyron, according to Buffum (36), began to lose their hoofs the second year, and in some cases the manes and tails came out. In some cases the horses would not be affected for one or two months, and in other cases they would show signs in a few days. The symptoms were those of ergot poisoning.

Pammel claims that most of the ergotism in the United States results from the ergot on various species of Elymus, and in Iowa on Elymus robustus, which is a common plant almost everywhere.

The action of ergot depends, according to Möller, on the age of the sclerotia. Four grams of newly gathered ergot is enough to cause marked illness in hens. Considerably later ten grams were necessary to cause illness, while five months-old ergot had scarcely any poisoning effect.

Remedy for Ergotism

There is no effective antidote for ergot poisoning, and the control measures known are primarily preventive.

The first essential in the treatment of ergotism is the removal of the cause.

Tannic acid, the chemical antidote is given to neutralize the unabsorbed portion of the poison. Chloral is the physiological antidote. In addition to giving the antidote the treatment is entirely symptomatic. Brown and Rank (32) recommend epsom or Glauber salts. In mild cases, such as wounds on the tail or ears, they should be cleaned with carbolic acid and then treated as an ordinary wound.

As only old sclerotia are poisonous, Brown (32) recommends mowing the pastures one or more times during the late summer and autumn, or as often as young sclerotia become abundant. The grass for hay should be cut while in blossom so as to prevent the formation of sclerotia.

Willirms (298) claims that good pure water is a very important factor in ergotism. Animals not having sufficient and pure water suffer more from ergot.

Lack of proper shelter during cold winter weather is favorable to the disease, since the poison affects the circulation of the blood. Stock allowed to begin in winter in poor condition are more liable to be seriously affected.

Grain infested with ergot should be cleaned by screening by fanning it from the largest part of the sclerotia before giving it to the stock. According to Wienzierl (292) 0.1 per cent of ergot by weight in grain is not objectionable.

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